DOCUMENT RESUME

ED 025 439 SE 006 060

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An Exploratory Project on Training Elementary Teachers in Mathematics and Science.
Kansas State Teachers College, Emporia.; San Jose State Coll., Calif.
Pub Date Sep 68
Grant- NSF-GW-3402
Note- 130p.
EDRS Price MF-$0.75 HC-$6.60
Descriptors- Conference Reports, *Curriculum Development, Educational Objectives, Elementary School Mathematics, *Elementary School Science, Inservice Teacher Education, *Teacher Education
Identifiers- Belmont Conference, National Science Foundation

Reported are the proceedings of a conference on the problems of training elementary teachers in mathematics and science. A small group of scientists, educators, and researchers representing school teachers from the elementary level through college, science and mathematics administrators and educators, scientists, government officials, and representatives from science and mathematics related industries met to take first steps in dealing with the problems. Goals of the conference were to produce action resolutions and recommendations which, when implemented, would (1) be effective in improving the science and mathematics curricula reaching the elementary school pupil, and (2) bring about integration of teaching of mathematics and science in the elementary school classroom. Specifically considered were the curriculum, the preservice and inservice training of teachers, and the capacity of American public school systems to respond to a changing curriculum. Several recommendations and guidelines for action were developed relating specifically to school administrators, classroom teachers, supervisors, and college and university personnel. (GR)

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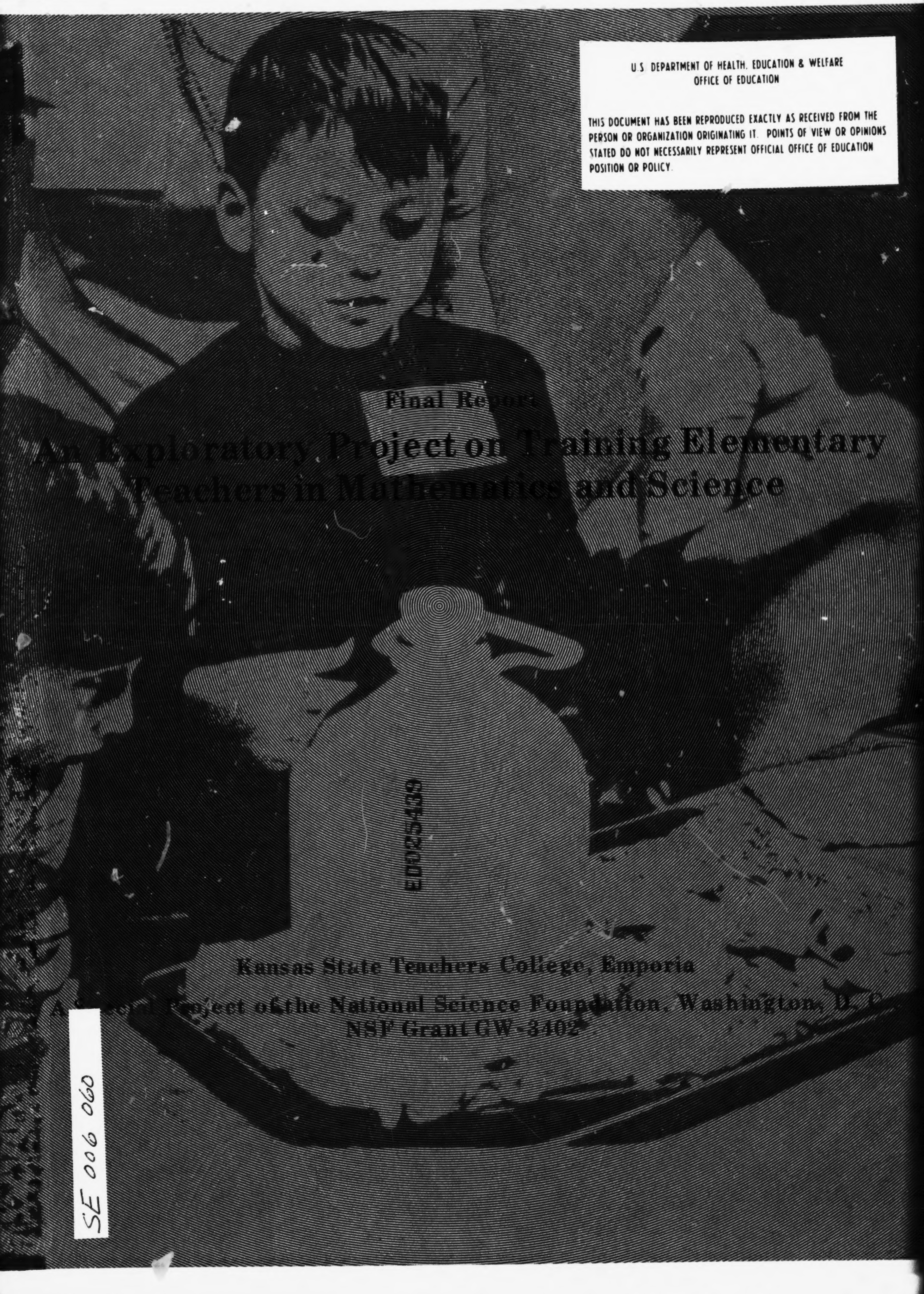

Final Report

An Exploratory Project on Training Elementary Teachers in Mathematics and Science

ED025439

Kansas State Teachers College, Emporia

A Special Project of the National Science Foundation, Washington, D. C.
NSF Grant GW-3402

SE 006 060

AN EXPLORATORY PROJECT ON TRAINING ELEMENTARY TEACHERS IN MATHEMATICS AND SCIENCE

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Final Report

Special Project GW-3402
National Science Foundation

Kansas State Teachers College Press
September, 1968

ACKNOWLEDGEMENTS

The Project Director is deeply grateful to the participants of the Belmont Conference whose time, experience and wisdom provided the content of this report.

A special debt of gratitude is expressed for the excellent thinking which went into preparing the position papers and the response papers presented at the Conference by Robert Davis, Director, Madison Project; Leonard Feldman, Mathematics Department, San Jose State College; Mary Nesbitt, Mathematics Supervisor, Dade County Florida; James Werntz, Director, Minnemast Project and George Katagari, Consultant in Science, Oregon State Department of Education.

The Assistance of Elizabeth Wilson of the Montgomery County Maryland Public School system; Ted Andrews, Research Council of America and David Barry, Dean of Sciences and Mathematics; San Jose State College in Conducting the conference and its evaluation was extremely important to its success and is greatfully acknowledged. A special note of appreciation is due to David Barry for assistance in preparing and reviewing the manuscript of this report.

The Kansas State Teachers College, Emporia, Kansas and the National Science Foundation both contributed to moral and financial support needed to conduct the Belmont Conference. To these organizations the Director wishes to acknowledge his sincere gratitude.

Glenn H. Crumb
Project Director

The Belmont Conference was directed by Glenn H. Crumb, Professor of Physical Science, Kansas State Teachers College, Emporia, Kansas and supported by funds provided by the National Science Foundation, Washington, D. C.

CONTENTS

Page

REVIEW OF THE CONFERENCE 1

Introduction. 1
Organization. 1
Goals 2
Ideas Expressed 3
Conference Tone 5
Areas of Emphasis 7
Quietus 14

POSITION PAPERS AND RESPONSES. . . . . Appendix A

"Organizing and Implementing an Integrated Science-Mathematics Curriculum in Elementary Schools", Richard Greenberg and Mary Nesbit 17

Response by George Katagari 20

"Can we Organize the Content, the Children, the Adults, and the Resources?", Robert Davis 24

Response by James Werntz. 74

"Effective Models for Training Teachers", Leonard Feldman 82

Response by Glenn H. Crumb. 95

CONFERENCE RECOMMENDATIONS . . . . Appendix B

Research and Development. 105

Institutional Modification. 111

Institution Building. 115

Communications. 122

PARTICIPANTS AND OBSERVERS AT BELMONT CONFERENCE . . . . Appendix C

A. Introduction

The administrative organization and the physical facilities of the American public school system, particularly in large urban and suburban areas, may be inhibiting, if not prohibiting, adoption and effective use of modern science and mathematics education programs. Twenty-five scientists, educators and researchers from throughout the country believe that it is not too late to institute a massive, nation-wide retraining program for teachers and administrators in an effort to alter the situation.

A growing concern is being expressed by scientists and laymen that the many modern curricula being developed by federally supported programs for use in the elementary schools are not reaching the pupils for which they are intended.

These persons, representing school teachers from the elementary level through college, science and mathematics administrators and educators, scientists, government officials, and representatives from science and mathematics related industries, met in June, 1968, at the Belmont Conference facilities of the Smithsonian Institution near Baltimore, Maryland, to take the first steps in dealing with the problem as they saw it.

B. Organization

The meeting was sponsored by a National Science Foundation Project which grew out of an U. S. Office of Education ESEA Title III Program developed by faculty members at Kansas State Teachers College, Emporia, Kansas to assist rural schools in the region surrounding the College. While working with the teachers and school administrators of these schools it became apparent that these persons were relatively unaware of programs in science and mathematics which could be adopted in their schools. It was further evident that personnel who became informed about the new curricula materials most enthusiastically adopted them. However, some teachers and school officials remained skeptical and provided sufficient barriers to prevent innovation from being introduced into the conventional programs. A series of meetings at San Jose State College, University of Texas and Kansas State Teachers College culminated in the plans for a conference on this problem to be supported by the National Science Foundation by a grant to Kansas State Teachers College, Emporia, Kansas.

C. Goals

The Belmont Conference had as its major goal the support of professional discussion and development of action resolutions or recommendations which, when implemented, would: (1) be effective in improving the science and mathematics curricula reaching the elementary school pupil and (2) bring about integration of teaching of mathematics and science in the elementary school classroom. Specifically considered were the curriculum, the pre-service and in-service training of teachers, and the capacity of American public school systems to respond to a changing curriculum.

Because the conference was designed to provide the participants with opportunity to interact directly concerning problems facing math-science education, the number of persons was kept small. The twenty-three participants and the limited number of observers were provided ample opportunity for productive work during the work sessions as well as after hours. The facility selected for the conference assured quiet, privacy and a favorable atmosphere.

D. Ideas Expressed

The focus of the Belmont Conference was strongly influenced by three position papers prepared and distributed to the participants for study prior to their arrival at the conference (See appendix A). The focus of each positon paper was guided by the conference director who formulated task charges to the authors. Each task outline dealt with basic questions from those slated in the project proposal funded by the National Science Foundation. The following three papers were distributed to all participants for review and consideration in advance of the conference:

(1) Can We Organize the Content, the Children, the Adults, and the Resources?[1]

(2) Effective Models for Training Teachers[2]

(3) Organizing and Implementing an Integrated Science-Mathematics Curriculum in Elementary Schools[3]

The questions which authors were asked to develop in their papers were:

(1) Is it possible to train or retrain the elementary school teachers of the nation in a fashion such that modern mathematics and science programs will reach the pupils at that level? Is it necessary?

(2) What should be the plan of attack if it is desirable to upgrade the level of instruction pupils are receiving in science and mathematics at the elementary school level?

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[1] Dr. Robert Davis (See Appendix A)

[2] Dr. Leonard Feldman (See Appendix A)

[3] Mrs. Mary Nesbit (See Appendix A)

(3) Are there now in existence college and university personnel who could provide regional leadership in developing projects to improve the elementary school science and mathematics offerings? How can they be identified?

(4) Is there a need for a national office or center to coordinate operation to attack the problem--does one exist now without clear identification?

(5) How can adequate manpower be developed to carry out a massive elementary school teacher training program?

(6) What are the necessary ingredients of a successful teacher education program which introduces the new science and mathematics curriculum at the pupil level?

(7) Can the second or third generation teacher in a pyramid approach (teachers teaching peers) act as an effective agent for program adoption? Consider teachers cross-training in mathematics and science.

(8) What role can the Elementary-Secondary Education Act with its various titles, the Education Professions Act and the Higher Education Act play in seeking a solution to the problem of support for teacher education or leadership development?

(9) What types of consortiums of colleges, universities, and school systems may be successful in attacking the problem of teacher education or retraining?

(10) What types of organizational structures are most economical in affecting classroom level change in the teaching of science and mathematics in the elementary school?

(11) What are the necessary relationships that should be found to exist between science and mathematics at the elementary school level? (Reference here is the Cambridge Conference of September, 1967)

Each author included other items as they deemed pertinent to improvement of the math-science curriculum which reaches the elementary school pupil.

The Director charged three additional persons to prepare responses one to each of the position papers, for presentation in the opening sessions of the Conference.[4] Following presentation of each response paper, discussion and debate was held to assure clarification of points and discussion on the position paper and the related response paper. All authors were present and entered freely in the dialogue. This discourse provided a basis for the extended debate and formulation of resolutions which took place in the small work group sessions and the eventual formulation of the resolutions adopted by the Belmont Conference.

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[4] (See Appendix B)

Prior to the close of the conference, all participants met in general session to hear and debate resolutions of the three working groups. All resolutions produced by this conference were thoroughly discussed and adopted by vote with all participants present.[5]

E. Conference Tone

Beyond the specific recommendations and exchange of professional ideas which resulted from the conference, other general results were evident which the evaluators deemed significant. These results as inferences or observations are only supported indirectly by evidence and data available in the position papers, in the responses to the position papers or the resolutions and their rationale. They are derived from review of audio-tapes which were made of the dialogue which took place at all the conference sessions and from the conference experience of the evaluations.

1. Unanimous Opinion Expressed. There was unity of opinion among the conferees concerning issues discussed. As evidenced by the long list of recommendations, representatives from all levels of education and industry were able to reach quick agreement concerning certain

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[5] (See Appendix C)

needs in public school education. No level of education or group was singled out for special criticism. The problems were recognized as fundamental and pervasive. The emphasis of discussion focused on a search for solutions to the problems posed. It was generally agreed that no simplistic panaceas would suffice but substantial attempts must be made to correct some major limiting faults in our educational establishment.

2. "Educational Lag" Reports. That a lag exists in "science education", was accepted without question. The several curricula which have resulted from the massive federal funding activities have not, in general, reached the pupils in the classroom. At least it has not reached them in a form or through the pedagogical methods deemed most effective. However, the major problem for the contemporary elementary school is one of having any science curriculum which is not, in the final analysis, merely a series of reading courses or lessons selected out of context without plan or supporting experiences from a "science textbook". The conferees expressed their concern for action in assuring that the available new programs become incorporated into the curriculum and that they be appropriately presented and taught.

3. Integration of Math-Science. The conference was designed to deal with implementation of math and science programs in the schools. The interface(s) between these two subject fields although central, did not limit subjects of discussion. The conferees repeatedly gave attention to this aspect of the problems, but no substantial progress was made in exploring it. Perhaps the reasons for this are to be

found in the historic division of the academic fields and the need for changes in school organization and administration to enable development of specific solutions. Expressions about the insufficient breadth of available materials and the inadequate trials of existing materials were frequent. Despite this, the conference voiced the need for a nation-wide attempt to associate mathematics and science in teaching at essentially all levels of education, kindergarten through college. It should be noted, however, that this statement refers to the teaching of science and mathematics _within the context of the modern contemporary approaches_ that have been developed.

4. _Diversity Theme_. Diversity in pedagogical approaches and in variety of teaching materials was a frequently mentioned need. The conference supported the continued efforts of the funding agencies including the federal government to assure diversity in this regard. Chief among the problems associated with this approach is that some of the problems that evolve are not sufficiently researched prior to their adoption. The constant search for panaceas and avoidance of excellence in evaluation of teaching by the educational establishment may have a great deal to do with this. The "system" may have to shoulder a major portion of the blame in this regard.

F. _Areas of Emphasis_

Some of the following points will be documented more extensively in other parts of this report. Stress placed upon them by the conferees necessitates their consideration. They are identified separately here because of their central role in the Belmont Conference discussions.

1. _Next Logical Step_. In order to assure continuing study on the prob-

lems discussed at Belmont, it was the consensus of the conference that steps should be taken immediately to establish regional consortial centers which would devote their attention to the integration of math and science into effective curricula for the various educational levels. The regional nature of the consortial centers would enable staff to give attention to the special problems unique to each locality and provide for involvement and training of local teaching personnel. It must be emphasized that the centers proposed do not in any way compare or conflict with existing structures in the educational establishment. Although the general model proposed for a center is similar to the historic model developed between the U. S. Department of Agriculture, the land-grant colleges, the country agricultural extension agents and the American farmer, appropriate modifications need to be explored. A logical step thus would be the establishment of a pilot model of a regional consortium based upon land grant extension service patterns to be used for study and, ultimately, perhaps as a model to be replicated elsewhere in the U. S.

The form of the Consortium appropriately should vary with regional interests. It should be established under governance that is separate from state departments of education, and/or existing educational centers. It could be associated with a land grant university with extension service administration. It could be organized as a separate agency with close cooperate membership and governance with existing institutions. It must involve the inter-dependent elements of the educational community, the campus, the school, the government, and the emergent educational industry in complement and juxtapositon. (see appendix C).

A primary function of the proposed consortium as seen by the conferees would be to establish programs that would bring togehter elements of the general community to serve as logical resources for improvement of the curriculum in schools. The organization would attract the talents of professional scientists and mathematicians, school teachers and administrators, science educators, industrialists, students at all levels, and society in general. The pivot of the system could be set in several existing parts of the educational establishment, but the Belmont conferees believed that success would most likely be found in an expansion of traditional "ties" to increase involvement of schools with colleges, universities and industrial complexes. The reason being the school cannot flower in isolation from contemporary society. These organizations have manpower in math and sciences whose talents must be utilized in development of educational programs.

To assure reduction of the "science education lag" the consortium would of necessity be a dynamic center for research, development and dissemination of information. This, according to the conference membership, defines the need for participation by the researcher, science educator, teacher, administrator, industrialists, students and the community in general. Significantly greater attention must be given to the continued need for in-service teacher education. It was a general conclusion of the conference that colleges preparing teachers have, to a major degree, "lost contact" with science, with educational industry, and the school classroom. The Belmont Conference did not emphasize the need for greater involvement of college and university faculties in order to assure that the varied elements in our changing society are reflected in new or existing curricula for teacher education. The need to directly incorporate capacity for change and innovation in administrative patterns of a consortium was stressed.

2. Attacks "Establishment". Although those at Belmont agreed that American schools provide some levels of our society with experiences worthy of our times, they expressed feelings of continued urgency to improve approaches to the educational problems encountered in the inner city, the suburban schools and the deprived rural areas. The inner city youth of America's great monolithic school systems have essentially been "turned off" by the educational establishment. The suburban youth too frequently finds himself driven to extremes of physical and mental agony to achieve high grades to gain entrance to a major prestigious institution of higher learning - only to find himself marking time until graduation. The rural youth finds himself culturally isolated from contact with the social, cultural and industrial complexities of the big city - in which he will most likely be forced to seek employment.

The existing educational establishment has not been effective in coping with these problems. The educational establishment has made various attempts to inculate mechanisms for change or acceptance of educational innovations, but only isolated progress can be reported. It was the conference conclusion that to affect any change in present math-science curriculum, and other areas, a substantial modification in the existing establishment structures would be required.

Under particularly heavy attack were physical facilities and structures of the classroom, the teacher-centered program, and the rigid regulations on pupil behavior and movement all of which force a potential active learner to become merely a passive observer. These conditions are strongly reinforced by approaches to school administration which enforce a quiet, rigidly controlled classroom that depresses pupil activity and involvement in learning situations. Both of these structures tend to negate individuality. They must be changed if we are to affect successful adoption of individualized modern math-science curricula.

Opportunity must be provided for innovations by teachers and for differential approaches to learning behavior. It was observed that the products (graduating pupils) of America's educational institutions are remarkably alike, when, in fact, education (learning) should tend to enhance differences among them. It was the belief of those at Belmont that "the establishment" tends to promote mediocrity by its "conformist" reward system. Hence it effectively blocks innovation and change on the part of the teacher, the pupil, and the curriculum.

3. New Links Proposed. Although the conference was highly critical of much of contemporary education, it was not without realistic recommendations which could help the situation. Furthermore, it was pointed out that not all responsibility for our problems could be placed on the pre-college schools. Because of extreme laxity in teacher preparation programs, the absence of enlightened, relevant programs for school administrators and the frequent lack of cooperation between the

"school of education" and "the academic" schools, faculties and colleges and universities must accept their share of the responsibility for our problems.

The Belmont Conference concluded that colleges and universities must turn their attention to improvement of undergraduate curricula in teacher education. They must demand superior teaching in substantive courses in science and mathematics provided for the prospective teacher. The specialized college instructor too frequently becomes the model of science and math instruction for teachers with limited backgrounds in the fields.

What a prospective teacher frequently "sees" as a model of science and mathematics instruction is a fact centered, rigorous presentation of the subject with little or no emphasis upon the processes of science. Since the prospective teacher has little chance to explore science beyond the introductory or "general" course he has no opportunity to place fact and processes in a proper framework for use in teaching. Pedagogy based upon this model misrepresents math-science to the student and unfortunately results in disillusionment and rejection of this essential area of contemporary human experience. The pupils thus reflect the limitations which are placed upon their teacher by the system. Greatly improved pre-service teacher education programs were consistently called for by the Belmont conferees as the ultimate long-range answer to many of our nation's educational ills.

According to conference participants, in-service teacher education programs are frequently misdirected. The guidelines for courses taken by potential research scientists often do not apply when planning for teacher education. Goals for in-service teacher education need to be redefined and refined at most colleges and universities. Close attention must be given to the possibility of college-school cooperation in a consortium for production of self-instructional materials and other programs for continuing in-service education.

It was further recommended that college and university faculties in science, math and education work closely together to develop curricular sequences involving integration of math and science in keeping with modern educational philosophy and teaching methods. This was not meant to be construed as a "methods" experience in each science or math course taken, but to be consistent exposure and involvement with superior teaching, involving the interfaces of the two areas.

In addition to the concept of the consortium, two other major "missing links" in the educational establishment were discussed at length. It was a conference conclusion that persons trained in math-science should be provided each elementary school and assigned major responsibility for the curriculum in these two areas. It was felt that the assistance of the "home teacher" must of necessity be expected, but the key educational role should be fulfilled by trained specialists. This follows the present pattern in which school systems provide special instruction in music and physical education. In an "age of science" we can do no less.

Although there was some difference of opinion, the central role of a mathematics-science activities room or area for each elementary school building was also supported strongly. It was deplored that existing facilities in some instances prohibit such space utilization. Difference of opinion rested on whether this problem could be dealt with in isolation from the pressing need for general expansion and improvement of inner city school facilities. It was reported that in at least one of the states with a major population growth rate all new elementary school buildings are now required to provide for such space. This is a promising precedent.

G. Quietus

The Belmont Conference participants represented a wide geographic distribution and great diversity of fields of interest. Many were involved with nationally recognized educational projects and institutions. Their conclusions must be seriously considered. They represent a serious and significant cross-section of our national professional leadership and educational experience.

The resolutions and recommendations of the conference are directed to the attention of the scientific community. This segment of American society must increasingly share in the leadership for our educational programs as they relate to the progress of our science-based society. They are also directed to the attention and scrutiny of the private foundations and public agencies. These groups are the critical links that can provide the important support elements in the implementation of the resolutions drawn by the conference.

Because of the severity of the criticisms, much of it self-directed, this report should be called to the attention of the educational establishment. This includes college and graduate school faculties and their administrators; boards of control and other appropriate governing bodies; school teachers, school administrators at various levels; and federal, state and local boards and administrative units.

Finally, the action and recommendations of the Belmont Conference are directed to the attention of the layman and his representatives in the various levels of government. As President John Adams said, "The preservation of knowledge among the lowest ranks is of more importance to the public than all the property of all the rich men in the country." We can do no less than follow his leadership and take steps to assure excellence at all levels of our American educational system.

APPENDIX A

Position Papers and Responses

Organizing and Implementing an Integrated Science-Mathematics Curriculum in Elementary Schools

Richard Greenberg and Mary Y. Nesbit, Dade County, Florida

The Problem

Participants in the Cambridge conference on school mathematics came to the conclusion that the advantages of combining science and mathematics instruction will far outweigh any disadvantages in the elementary schools.

In the elementary school curriculum in the past, science and mathematics have been taught as isolated subjects. Also, in many situations due to their background and preparation, teachers have felt an inadequacy in both fields. There has been little stress on the interrelationship and integration of math and science. Previously, teaching emphasis has been on teacher-direction rather than student involvement. Such a situation does not need to continue.

Because of the advances made in updating science and mathematics instruction it is now possible to present an educational program which successfully integrates science and mathematics in a way that is personally meaningful to each and every student. In order to cultivate a positive attitude on the part of teachers toward these subject areas, to develop teaching methods utilizing the discovery approach, and to capitalize on the relationship between these two areas through carefully planned reinforcement activities, the following topics must be carefully examined, analyzed and developed.

Adapting the Program to Varied Economic Cultural and Geographic Areas

Because science and mathematics pervade all environments, the materials can be readily adjusted to meet the needs of various cultural groups. Inner city children and others with cultural and language barriers, therefore, can adapt to a process approach science-math program. The units developed could be such that they excite and involve the students at their level of involvement with the goal of developing their curiosity and improving their performance. The teachers, however, must be stringently selected and educated to handle the special needs of these children.

The Development of a Plan for Better Teacher Education to Upgrade Instruction

In order to develop initially adequate personnel, it will be necessary to set up an institute to educate science-math laboratory teachers. These people will be selected on the basis of:

1. teaching performance
2. adequate AAAS background
3. adequate modern mathematics background

After the teachers are selected, they will participate in an eight-week summer institute involving intensive training in an integrated science-math teaching approach with an extensive background in the psychology of how children learn in order to become more aware of children's needs. Prior to the summer institute, a planning and orientation period should be provided.

One of the primary purposes of the summer institute will be the development of a teaching manual. This guide should be of the nature of a super-manual which catalogues and describes the actual sequence of units and their development.

After the completion of this summer institute, these laboratory teachers would be assigned to pilot elementary schools to work with and train carefully selected classroom teachers called coordinating teachers. These coordinating teachers would be selected by the science and mathematics supervisors, the directors, and the principals involved. These teachers would be given part-time duties so that they would have a part of each day to work with children and the laboratory teacher during the year's training period. This approach has been successful in training coordinating mathematics teachers in Dade County. The laboratory and coordinating teachers would meet periodically with the institute director throughout the school year. This effort requires continuous inservice training over a minimum of three years as cadres of teachers are educated, programs modified to suit the areas involved, and procedures or methods instituted to bring improvement to classroom teaching.

The Possibility of Training and Retraining Every Teacher

It would be an exceptionally difficult task to train and/or retrain all elementary school teachers of the nation to function as successful science-math teachers. Initially, teachers who are unaccustomed to the activity and process approach to teaching should not be selected since it would only complicate the task. It would be more advisable, at the onset, to attempt to develop further those teachers who have both the interest and background in these specific curriculum areas.

The Need for a National Office or Center

A well-identified standing committee should be established for the following purposes:

1. to provide leadership, guidelines and resource people

2. to coordinate efforts

3. to disseminate information and research

It would also be advisable to coordinate, through a specific clearinghouse, e.g., ERIC, the flow of information regarding the various programs throughout the country. The leadership of this clearinghouse, which would include prominent scientists, mathematicians and educators, would be a source of motivation for individual projects. Financial support at the national level could be secured by National Science Foundation funds. On the state and regional levels, assistance is essential from ESEA FUNDS.

Titles I and III of ESEA could provide funds for the released time and training of the coordinating teachers.

Title III of ESEA plus the recently enacted Education Professions Development Act of 1967, would be a source of revenue for the two consecutive summer sessions plus inservice work for the academic year.

Suggested Advantageous Organizational Structures for Science and Mathematics in the Elementary Schools

Due to the complexity of our present-day elementary school curriculum, it would seem advisable to consider the possibilities of departmentalization or team teaching at the elementary level, particularly in the intermediate grades. Qualified specialists for this program could be drawn from the coordinating teachers educated at the various schools by the science-math laboratory teachers. Science-math laboratories should be set up in districts and later in each school as the teachers are educated.

Types of Consortiums of Colleges, Universities and School Systems Which Would be Successful in Attacking the Problem of Teacher Education or Retraining

It would be advisable to ask colleges to employ the locally trained specialists to instruct updated mathematics and science courses giving emphasis to the discovery approach where content and method are not separate.

There should be full cooperating and involvement of both colleges and universities and math-science specialists for implementing the undergraduate training program. Undergraduate students could spend half of their course time observing and working with trained specialists in the schools.

Necessary Relationships Existing Between Science and Mathematics at the Elementary School Level

In examining the necessary relationships that should be found to exist between science and mathematics at the elementary school level the following can be found:

1. methods and materials utilized in instruction
2. relationships in curriculum between content and method
3. teacher-pupil involvement and skill utilization in science-math topics

"Organizing and Implementing an Integrated Science-Mathematics Curriculum in Elementary Schools" - A Response*

Dr. George Katagiri
Science Consultant
State Department
of Education, Oregon

I think what is described in Mary Nesbitt's paper is a model that is partially operating in Dade County Florida. I was confused as to what was existing at the present and what was being proposed. The primary concern of the program was to develop and implement an integrated elementary science and mathematics program. At the present time, I am not convinced that the elementary science and mathematics material can be readily integrated in a single summer. Perhaps it might be possible to develop supplementary materials for limited use. The math people do not feel that the existing elementary science materials contain an adequate amount of math for a program. In some places some of the math concepts in the materials are quite adequate; such as certain parts of AAAS and graphs in ESS units. These do not constitute the elementary science and math program. A question that is frequently raised is should or can math be completely integrated with the science program. I doubt very much than an eight (8) week institute of laboratory teachers can develop an integrated sequential manual described in the paper. However, this should not detract us from our efforts of implementing existing programs. I think we could be completely justified in establishing a climate for continual development for change.

This paper emphasized the need to develop in teachers a positive image toward science and mathematics instruction. Administrators, parents and community must be added to this list. I find that it is difficult to convince administrators and parents of the need to improve instruction. Extension or in-service education for both teachers and administrators is necessary. Those situations where we find the most effect are where there was both teacher and administrative commitments to the program. Commitment of time, money and moral support. I concur with the paper that the teachers need to have a resource teacher or coordinating teacher available in the building who is knowledgeable about the program and knows how to assist with problems as they arise. Any implementation program should recommend the designation of a person as a resource teacher.

I agree with the paper's point of view regarding social, economic and cultural groups. As long as the activities and materials have relevance to the student, there should be little difficulty in reaching children regardless of their backgrounds. Science and math are two areas which should have

* A response to the position paper by Mary Nesbitt. Belmont Conference, Belmont Estate, June 26-29, 1968

the least difficulty in developing instructional materials which have this kind of relevance. The paper refers to the need for a process approach. My interpretation of the term process approach as used in this paper is that it refers directly to the AAAS program. So far as the Dade County model is concerned, I can see where identification with a particular program can be justified. I have encouraged several school districts in Oregon to identify with a single program. However, I could not follow the same action for the entire state. I doubt that this conference would do the same for the nation. I think that the Processes of Science as identified by AAAS program are directly or indirectly developed in most of the other science programs and I feel they should be emphasized in any resolutions coming from this conference.

The paper speaks of teacher education and upgrading of teachers. Again, with this identified objective, the implementation of AAAS, the Dade County plan for the training laboratory and coordinating teachers should work. However, if the program is operated on a national level and if the program presented alternatives, the size of the task would increase exponentially. I think we should explore a number of approaches including the one detailed in the paper. Perhaps, an effective avenue would be to work with those responsible for teacher training at the present time. In our particular situation at the State Department of Education in Oregon, I have been working with the Director of Teacher Education in planning a program to inform teacher personnel in the public and private universities and colleges of the new programs in elementary science. In December, we held a 5 day conference to introduce this group of people to the AAAS program. In May, we had a full day session to introduce the same group to the ESS material and a second day to introduce the same group to the SCIS materials. The attendance was good especially when the invitation went out directly to the Dean of the schools. I have not stopped to ask why math or the other subjects haven't done the same. Part of the answer perhaps, is that the planning for these conferences was quite time consuming. Probably a more basic answer is that the individuals involved worked harmoniously together. I think this natural relationship is most important to take into consideration. The wrong individual although quite qualified is often quite ineffective in communicating.

With regard to in-service training of principals, curriculum directors, science supervisors, and head teachers all were invited to our AAAS workshop which lasted five days. There were about forty in attendance from all over the state, each paying his own expenses. I was hoping they all would be qualified to run their own program by the end of the week, but after five days I felt that only a few were capable of conducting their own programs back in their own districts. Currently there is a clamor for persons to conduct in-service programs in different parts of the state. I think we have enough individuals to conduct these programs in the Portland area because many individuals were a part of the pilot program in the past year. I am not sure about the other parts of the state.

Here is another point. I could not have conducted workshops in SCIS, AAAS, and ESS had I not spent one week in Berkeley, eight weeks in Newton and fourteen days at the University of Maryland in workshops. There needs to be an adequate number of personnel to conduct workshops who have the time. In this regard an eight week summer workshop with carefully selected participants might be long enough to train laboratory teachers to be on call in many regions of the United States. So far as training every teacher in the United States is concerned, I don't know. I tend to be a pessimist on this point.

I concur with the paper that there needs to be a national center. Its purpose should include those items listed on the paper but in addition it should be a teacher training center to train teacher training personnel, science and math supervisors, consultants, coordinators and also to train pre-service and in-service teachers to use existing materials. During the school year, the staff at the center could conduct training sessions in local communities. During the summer, school personnel could come to the center for training. I think the center should be primarily concerned with the implementation of existing materials and not in development of materials or altering the present programs, at least until they are released to the public domain.

With regard to the organizational structure in the school, my single negative reaction to the paper is directed at the suggestion that departmentalization be considered and that there be developed a math-science laboratory for each elementary building. I tend to react more favorably to the team teaching idea of math-science instruction. My point of view rests on several premises which I present at this time.

In the first place we have about 100% of the children in the community attending the elementary school. Perhaps the primary purpose for the math and science program would be to acquaint all students with the world around them as much as possible in their elementary years. At the end of this time, these youngsters would have competency in using the processes of science so that they could continue to learn for themselves as they mature. Eventually, we would expect them to keep up-do-date as any literate adult. Now teachers are supposedly literate adults. If science is taught by special people in special places with special science things, I don't think we can convey this image to children. If the elementary science and math program can't be learned by our elementary teaching core, maybe the program should be changed. It may be that in some situation we may need to start a program with trained instructors however, I hope to see the eventual development of science competencies among all elementary teachers.

The suggestions in the paper for schools to cooperate with colleges, I think, is commendable. Many public school teachers and supervisors who have had direct experiences in the newer programs can contribute much to college courses. During the summer, in Oregon at least, we know that where classroom teachers have teamed up with college instructors to introduce new courses such as AAAS, Time Space Matter, ESCP, ESS, and IPS, the courses have been highly successful. Perhaps, it might be of interest if I would explain that in Oregon, as in many states, the State Department has legal jurisdiction over the materials being used in the classroom. In these instances that I have mentioned, these programs were introduced to the State Department of Education but even though we had state textbook adoption and these materials were not on the list, the State Department was able to introduce them on a pilot basis. So we coordinate our efforts with the school districts in the fields and with the colleges to set up special training programs using the twenty to thirty pilot teachers in each one of these programs. I realize that these teachers are not pilot teachers in reality because these programs have been piloted extensively, but the nomenclature certainly helps so far as the legal technicalities are concerned. These courses have been successful. Many college instructors are happy to have this assistance of classroom teachers with experience in these programs.

In the final analysis, the significance of the Dade County Program, I think, lies in the fact that the leadership there is actively involved in the implementation of the new elementary program in the classrooms. We might raise the question, why did Dade County move ahead in this type of program and why did not ten other counties in the state move ahead in the same manner? I think the answer lies in the fact that there is leadership in Dade County in terms of individuals who have the initiative and have taken the opportunity to bring about change. The existence of position, I don't think, is enough. With regard to the implementation at the classroom level, another point of concern might be to identify those schools in Dade County which the program is working best. My guess would be that in those schools where there is administrative commitments, we will find the most successful programs in operation.

CAN WE ORGANIZE THE CONTENT, THE CHILDREN, THE ADULTS, AND THE RESOURCES?

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Director, The Madison Project

For once in my life I have the opportunity of attending a conference--this one--which seems to be directed at exactly the proper target. What we are asked to think about and talk about is precisely what we actually need to think about and talk about.

Therefore, for once in my life I shall attempt to hold myself rather strictly to the matter at hand, as proposed in Glenn Crumb's letter of April 18, 1968, and by the proposal to NSF. In order to stay on target, I shall return repeatedly to the charge which has been put to us.

Professor Crumb[1] describes this conference as "a project to explore the lethargic manner in which modern programs in science and mathematics are being adopted in the nation's elementary schools". Elsewhere the proposal excerpt (page 1) comments: "These modern programs have not reached the pupils for which they were intended on any broad scale however, _even when school systems report their adoption_ (italics mine. RBD)".

Our own considerable experience indicates that Professor Crumb is telling it like it is. In my own project, we ourselves have reached enough schools so that we can sit back and watch classes of our materials appear sporadically on TV--classes in Los Angeles and San Diego Schools were presented in a nationwide NBC News broadcast on June 22, 1967, produced by Craig Fisher; six half-hour shows presented classes of our materials over NBC News, Channel 4, in the New York City viewing area; a spot on NBC's _Today_ show presented a racially-integrated school that was (incidentally) using our materials; and classes of Madison Project materials were mentioned in a recent Sunday Magazine section of the New York Times.[2] Consequently, we can hardly claim that no one ever heard of our work. Edward Yeomans reports observing our materials in use in England[3], and Tamas Varga reports their use in Hungary.

I can't claim we have reached nobody at all. But we have reached hardly anyone, and the same goes for other "new" science and mathematics projects. If you drop a pin on a map of the United States, it is a safe bet that the nearest elementary school will be teaching traditional mathematics and science, and teaching it badly. We know, because we spend hundreds of hours in elementary schools, and this is what we see. We don't actually select our schools

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1. Letter of April 18, 1968

2. Mayer, Martin. "Frustration Is the Word for Ocean Hill", _The New York Times Magazine_ (May 19, 1968), pp. 28 ff.

3. Yeomans, Edward. _Education for Initiative and Responsibility_. National Association of Independent Schools, November, 1967.

by dropping pins on maps, but our selection procedure seems quite reasonably haphazard. Surprisingly much the same criticism can be made, with a few modifications, about teachers colleges. Some new CUPM courses may be in evidence, but prospective elementary school teachers are almost nowhere in learning what they will need if they are to participate effectively in improving elementary school math and science.

In the sense that I have just discussed, the "new math" and "new science" do not exist. At least, for the vast majority of teachers and students, they don't. Therefore, our conference is of unquestioned necessity and relevance. We must ask the question: Why? Why have we had so little success in improving American education? After all, we've been working on the problem for more than ten years...

I. Some Obvious Obstacles

In the first place, there have been some obvious obstacles. Even listing them may seem regretably banal, but not listing them would risk serious misunderstanding.

1. Appearances are cheap; realities are costly. One obstacle, surely obvious, is that it is easy to seem to have "new" math and science curricular, but it is very much harder to have them in fact. If you take a traditional arithmetic text, add some notations like $\{\ \}$, discuss binary numerals, and delete the words "borrow" and "carry", then you have "gone modern". This is the "instant mod" approach--cheap, easy, and ineffective. It goes over well with most parents, who appear to trust their schools. What the realities of an improved set of experiences in mathematics and science would be we shall try to suggest, in part, later on. To identify them fully would be a major task.

   At the college level, we can encourage (or require) prospective elementary teachers to memorize the axioms for an ordered field, and to memorize the statements of some theorems and their proofs. If this is all we do--plus showing them Venn diagrams and words like "herd", "flock", "collection", "gaggle", and "gang" (so they won't be afraid of the word "set")--then I do not think we have equipped them to deal with the eight- or ten-year-old children they soon will be facing. Yet this inappropriate treatment of elementary education majors can be observed in our colleges and universities virtually from one coast to the other. I have seen it myself, and I have checked with others who report the same thing.

   It is actually possible to prepare college students (or practicing teachers) so that they are able to teach the new programs. The British Nuffield Mathematics Project does it, H.M.I. Miss Edith Biggs does it, Leonard Sealey does it, E.D.C. does it, and Webster College does it, to mention a few examples--examples which, significantly, are ordinarily ignored, rather than carefully studied as they deserve to be.

Ways of accomplishing effective teacher education--as well as reasons why it is not ordinarily accomplished--will be discussed below.

2. There are not Facilities Dedicated to Quality Innovation. The remark is obvious, but nevertheless shocking, like something which should not be mentioned in polite society. Who is responsible for quality innovation? I have actually known one man to lose his job because he was said not be have produced quality innovation, but he was headmaster of a rather unusual private school in St. Louis, so I suppose he doesn't count. Very few, indeed, are the teachers (out of a national total of 1.5×10^6) or superintendents who daily fear such a fate. Lose your job over LSD? Quite possible. Over sex? Quite possible. Over racial problems? Quite possible. Over right-wing politics? Quite possible. But over a failure to produce quality innovation? Look, man, it's like...

   Again, we shall consider some possible remedies presently.

3. The Challenge to Existing Organizations. Although Piaget and Bruner get the publicity, it's a toss-up as to whether Marshall McLuhan, Bel Kaufman, Stokeley Carmichael, David Harris, or Robert Ardrey is the fundamental educational philosopher of our time. Ardrey, citing ethology, has stressed status, seniority, group internal cohesion, territoriality, and group hostility to outsiders, as fundamental primate behaviors--which includes you and me and them.

   Now, who wants to create a new group to pursue a new line of attack? To do, that is to say, what schools of education, universities, state departments of education, and school systems have thus far failed to do, even though it's their turf we're treading on. Don't all volunteer at once...

   Again, we discuss this further below.

4. The Challenge to the Conventional Wisdom of Education. There is an authentic report of a physician who said that what he saw through higher-powered microscopes he dismissed as "theoretical", "controversial", or "not well-established".

   The conventional wisdom of education has often operated in precisely this way. One can, for example, show carefully authenticated films of actual classroom lessons, but one might as well show *Bewitched* or *Lost In Space*. However carefully you record classroom behavior, however remarkable the results you can show, people don't believe it is the thing that they perceive it is. Apparently everyone knows that films lie. Once deceived, forever sceptical. Yet we urgently need truthful recording on film and video-tape to show actual classroom lessons. Nothing else works equally well.

   By contrast, what one can show by questionnaires, sociograms, or multiple--choice tests is accepted as fact, man! Even though it tends to be precious little that you succeed in showing, and is irrelevant more often than not. The thing is, like, it's real hard data. At least, the conventional wisdom proclaims it as acceptable.

This, too, we shall consider presently.

Of course, the conventional wisdom is not limited to matters of admissable evidence. Nor is it in agreement with itself. One faction of the conventional wisdom holds that teaching is basically a matter of telling; whereas another faction of the conventionally wise assert that teaching is really a matter of drilling; conventional wisdom (one faction, that is) maintains that the goals of education are fully known (or so nearly so as makes no difference), that these goals can be described in fully explicit terms, and that a superior education program is one which achieves these explicity-stated goals at the least cost or in the least time, thereby in effect maximizing the productivity of the individual worker (you should pardon this phrase). The conventional wisdom also proclaims that in the year 2,000 everyone will have to be able to add and multiply accurately, reliably, and quickly, despite the fact that many serious scholars are rather in doubt about this requirement.

The conventional wisdom has also held that every question has exactly one right answer, which (at least in science and mathematics) is simple, absolute, and entirely, beautifully correct.

In all of these matters, as we shall see in detail, the conventional wisdom of schools has been at odds with the usual assumptions of scientists and scholars, and this has impeded the adoption of new curriculum materials into elementary schools. (As a matter of fact, our own very small-scale studies of secondary schools leave considerable doubt as to how much more successful the new programs have been there. That, however, is another matter. We are not presently asked to concern ourselves with it.)

5. We Are Asking People to Change Their Behavior; and Even Their Belief Systems. This "obstacle" is really a corollary of the preceding one. Traditionally teachers have told, drilled, and tested for identical rote recall. Hence the popularity of "2 + 2 = 4" as the paradigmatic learning task. But serious instruction in science and mathematics asks for something quite different.

Traditionally teachers have dealt in simple declarative statements where content was a simple, definite, absolute truth. (e.g., "Males have one more Y chromosome than females"; or "snow flakes always have six points", or "you can't subtract 8 from 4", or "French is the basic international language for the world".) Serious study of science and mathematics more often than not demands a rejection of such simple statements of absolute truth. Science--and, in fact, mathematics--necessarily deal with tentative statements, with statements of recognized ambiguity (Is "death" determined by the termination of the heartbeat, by the cessation of electrical activity in the brain, or by neither of the above?), with things that change instead of remaining the same, with statements of (perhaps temporarily) unknown truth value ("Let N be the largest positive integer, "or" suppose that the square root of 2 is $\frac{p}{q}$, where p and q are relatively prime positive integers"), and with many other stranger things in Heaven and earth than are dreamt of in the conventional philosophy of most schools, most teachers, and most textbooks.

Where many teachers are ordinarily rigid, we are asking them to change their behavior and become flexible. Where many teachers are ordinarily didactic, we are asking them to change their behavior and to allow children to explore on their own. Where many teachers ordinarily control their classroom tightly, we are asking them to change their behavior and to share some of this control with the children. Where many teachers believe they must always pretend to be the authority on everything, we are asking them to admit, at least occasionally, that they don't know the answers to some questions. Where many teachers feel particularly at home in a barren classroom equipped only with the tools of reading and writing--that is to say, pens, pencils, paper, books, chalk, chalkboards, bulletin boards, transparencies for overhead projectors, etc. --we are asking them to bring in Cuisenaire rods and meal worms and spiders and caterpillars and gerbils and batteries and containers of water--and even to go outside of their classroom and use surveying equipment, or make statistical frequence counts on different makes of automobiles that pass by.

Possibly one of the strongest claims I wish to make is that we cannot teach honest mathematics and honest science without asking many teachers--and I believe it is perhaps a majority of teachers--to change their behavior in significant ways. Now we all know that this must, then, constitute a very genuine obstacle indeed; nobody changes his behavior easily, lightly, or quickly. We are who we are. We can become different, but it takes effort, commitment, and time.

To make matters worse, it seems to me that mathematics--and perhaps even more conspicuously science--require of us that we change our beliefs. Nothing is "sacred". Nothing is "safe" and "guaranteed" and "permanent". Nothing, for that matter, is unmentionable. We can study patterns of taxation, the causes of poverty, the origins of species, the personality of assassins, human sexual reproduction, and the possibility that there is no rational number whose square is two.

Creative people have lived in this world, to a greater or a lesser degree, for over two thousand years. Nonetheless, this is a strange new world for most elementary school teachers. I doubt that many feel genuinely at home in it.

What we are asking--and it is our minimum possible demand unless we are to betray our own goals--is, in fact, a great deal. Should we be surprised as a "lethargic" response from schools and teachers?

6. A School Is No Place for Children. ...Or, rather, what we mean is that the vast majority of schools are not very suitable environments for learning. This has been documented so well and so often that we can add little to it here. Perhaps the best we can do is to quote Jonathan Kozol:

> Although Stephen did poorly in his school work, there was one thing he could do well. He was a fine artist. He

made delightful drawings. The thing about them that was good, however, was also the thing that got him into trouble. For they were not neat and orderly and organized but entirely random and casual, messy, somewhat unpredictable, seldom according to the instructions he had been given, and--in short--real drawings. For these drawings, Stephen received considerable embarrassment at the hands of the Art Teacher. This person was a lady no longer very young who had some rather fixed values and opinions about children and about teaching. Above all, her manner was marked by unusual confidence. She seldom would merely walk into her class but seemed always to sweep into it. Even for myself, her advent, at least in the beginning of the year, used to cause a wave of anxiety. For she came into our class generally in a mood of self-assurance and of almost punitive restlessness which never made one confident but which generally made me wonder what I had done wrong. In dealing with Stephen, I thought she could be quite overwhelming.

The Art Teacher's most common technique for art instruction was to pass out mimeographed designs and then to have the pupils fill them in according to a dictated or suggested color plan. An alternate approach was to stick up on the wall or on the blackboard some of the drawings on a particular subject that had been done in the previous years by predominantly white classes. These drawings, neat and ordered and very uniform, would be the models for our children. The art lesson, in effect, would be to copy what had been done before, and the neatest and most accurate reproductions of the original drawings would be the ones that would win the highest approval from the teacher. None of the new drawings, the Art Teacher would tell me frequently, was comparable to the work that had been done in former times, but at least the children in the class could try to copy good examples. The fact that they were being asked to copy something in which they could not believe because it was not of them and did not in any way correspond to their own interests did not occur to the Art Teacher, or if it did occur she did not say it. Like a number of other teachers at my school and in other schools of the same nature, she possessed a remarkable self defence apparatus, and anything that seriously threatened to disturb her point of view could be effectively denied.

How did a pupil like Stephen react to a teacher of this sort? Alone almost out of the entire class, I think that he absolutely turned off his signals while she was speaking and withdrew to his own private spot. At his desk he would sit silently while the Art Teacher was talking and performing. With a pencil, frequently stubby and end-bitten, he would scribble and fiddle and cock his head and whisper to himself throughout the time that the Art Teacher was going on. At

> length, when the art lesson officially began, he would perhaps push aside his little drawing and try the paint and paper that he had been given, usually using the watercolors freely and the paintbrush sloppily and a little bit defiantly and he would come up with things that certainly were delightful and personal and private, and full of his own nature.
>
> If Stephen began to fiddle around during a lesson, the Art Teacher generally would not notice him at first. When she did, both he and I and the children around him would prepare for trouble. For she would go at his desk with something truly like a vengeance and would shriek at him in a way that carried terror. "Give me that! Your paints are all muddy! You've made it a mess. Look at what he's done! He's mixed up the color! I don't know why we waste good paper on this child! Then: "Garbage! Junk! He gives me garbage and junk! And garbage is one thing I will not have." Now I thought that that garbage and junk was very nearly the only real artwork in the class. I do not know very much about painting, but I know enough to know that the Art Teacher did not know much about it either and that, furthermore, she did not know or care anything at all about the way in which you can destroy a human being. Stephen, in many ways already dying, died a second and third and fourth and final death before her anger.[4]

If this account from Jonathan Kozol does not convince you, consider for example the following description of I.S. 55, written by Martin Mayer, long known as a careful observer and accurate report:

> Designed long before anybody was talking of community involvement, I.S. 55 is a square, brown, brick fortress with crenelated walls. It has no obvious main entrance--its dark-brown metal grids. It seems admirably designed for defence: one feels looking at it that a handful of teachers armed only with a few pots of boiling oil could hold off the neighborhood indefinitely.
>
> The atmosphere inside matches the architectural impression, for this is a building where everybody--administration, teachers, children--is terrified of disorder. Seven to nine staff members are on hall patrol duty during every class period. Even when the halls are relatively empty, children are expected to stay on the right side of the permanent line down the middle, and to turn square corners. As anything

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4. Jonathan Kozol, Death At An Early Age. The Destruction of the Heart and Minds of Negro Children in the Boston Public Schools, Houghton Mifflin (1967) pp. 2-4.

> left in a locker is stolen almost immediately, the children keep their coats and books with them at all times; but anyone who actually wears a coat in the halls in sent to a guidance counselor, possibly home for the day. Further problems are created by faulty acoustical planning which gave the classrooms hard-surfaced, ridged ceilings. The resulting extraordinary resonance blurs even precise speech and amplifies that screaming of teachers and children which gives junior high schools their characteristic zoo-like roar.[5]

These are isolated items that may leave the reader unconvinced. If so, perhaps he should turn to a careful study by a scholarly sociologist: Louis Smith and William Geoffrey, The Complexities of an Urban Classroom, published by Holt, Rinehart & Winston, 1968.

Finally, of course, there is Bel Kaufman's best-selling Up The Down Staircase.

The fact remains: most schools are not suitable environments for learning. That is one reason why new science and math programs don't work in most schools, and it is one reason why new curricula in art, music, anthropology, political science, literature, and African history will fail in very much the same way. First they will emasculated, and then they will be taught--by drill--in an environment that is a combination of a zoo and a prison. If *your* school really does very much better, stay there!

7. Orders of Magnitude Too Small. Most efforts at implementing new curricula have been orders of magnitude too small. Probably we have had no choice. Probably we have done the best we knew how. Consider, however, Aaron Wilkavsky's remarks on programs to solve urban problems, including education:

> A recipe for violence: Promise a lot, deliver a little. Lead people to believe they will be much better off, but let there be no dramatic improvement. Try a variety of small programs, each interesting but marginal in impact and severely underfinanced. Avoid any attempted solution remotely comparable in size to the dimensions of the problem you are trying to solve. Have middle-class civil servants hire upper-class student radicals to use lower-class Negroes as a battering ram against the existing local political systems; then complain that people are going around disrupting things and chastize local politicians for not cooperating with those out to do them in. Get some poor people involved in local decision--making, only to discover that there is not enough at stake to be worth bothering about. Feel guilty about what has happened to black people; tell them you are surprised they have not revolted before;

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[5] Mayer, op. cit., p. 66.

> express shock and dismay when they follow your advice. Go in for a little force, just enough to anger, not enough to discourage. Feel guilty again; say you are surprised that worse has not happened. Alternate with a little suppression. Mix well, apply a match, and run...[6]

I think those of us associated with NSF Projects have avoided, more-or-less, the worse aspects of Professor Wildavsky's purgatory, but we should not dismiss his remarks without thinking about them.

In the spring of 1968, the budget of the New York City Schools was cut --suddenly--by 141.7 million dollars. If the schools can suffer cuts of that order of magnitude and still maintain business as usual, how much money will it cost to produce genuine improvements and significant innovations? Our present efforts are orders of magnitude too small.

8. Not an Answer to a Recognized Problem. The response of the schools has been "lethargic" in part because, while we believe in the importance (or even urgency) of what we are doing, the world of large does not. At best, any innovation becomes adopted rapidly if (and, with the possible exception of irrational fads, only if) it is perceived as an answer to a recognized problem.

Basic illiteracy is a recognized problem; effective methods of alleviating it can expect a quite energetic program of implementation. A cheap second car solves a real problem for many families, and Volkswagens, Renaults, and similar cars proliferate abundantly. Poverty is a recognized problem; anti-social behavior constitutes (more or less) a recognized problem; unemployability constitutes (again, more or less) a recognized problem. Hunger and starvation institute (still, unfortunately, "more or less") recognized problems. In every case we can expect at least modestly serious efforts at effective implementation. Yet, in even these cases, it is important to notice that really effective responses are rarely carried to completion. As one further example, smog is a more-or-less "recognized" problem, but the response here, too, has certainly been "lethargic".

If, as the case of smog (and most of the other examples just cited) suggest, even "recognized" problems can be ignored or inadequately dealt with--and the more one looks, the more this seems in fact to be the pattern--what can we expect of a "cure" for an unknown "disease"?

I don't mean to suggest that our work has been unnecessary. We who believe in an age of science, creativity, and individual self-realization see some very important reasons for doing precisely what we are trying to do.

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[6] Aaron Wildavsky, "The empty-head blues: black rebellion and white reaction", The Public Interest, number 11 (spring, 1968), pp. 3 - 4.

But do most teachers, most parents, or most administrators recognize any real need for a better, deeper, and more creative understanding of science and mathematics? Do they see this as something which can enrich the life of each individual, and help to shape a more positive orientation for our whole culture?

Sputnik gave people a reason to be concerned, and its effect on the public attitude was dramatic, but it provided the wrong kind of reason--and a temporary one, at that.

Now part of this is, I suspect, our own fault. We have understressed two important areas: the first, obviously, is public relations and "public education", but the second is equally important. We have not, in most cases, figured out for ourselves what we were mainly trying to do. Have we been trying to produce more creative geniuses and first caliber creative scholars? Trying to produce a large supply of sophisticated technicians for an economy that is racing toward new heights of profound technological sophistication? Trying to help the average dweller in a scientific age achieve the fullest possible self-realization? Trying to help solve the problems of non-achievers and the potentially unemployed? Trying to help a scientifically-based culture find its groping and uncertain way?

I submit that there has been virtually no discussion in responsible publications as to which of these goals we are pursuing, and by which methods. Possibly because of an unconscious egalitarianism, we seem to prefer to merge all of these goals into a single vision of "better curricula in math and science". This isn't entirely wrong--and it is turning out that all of these goals overlap one another quite considerably--but there are differences, and the smallest estimate of the price we have paid would be to say that, as a result of not discussing our goals, we have often been misunderstood. In fact, our actual programs themselves have probably been somewhat less effective than they might have been. The reason why you are doing something has a strong influence on the way you carry it out.

9. The Case of the Non-Existent Dialogue. "New math" curricula (and science curricula) have attracted the attention of

    mathematicians and physical scientists
    cognitive psychologists
    developmental psychologists
    social psychologists
    "task analysis" psychologists
    clinical psychologists

and many kinds of educators. These various groups have largely ignored one another. They have, in fact, not even taken the trouble to argue. We shall see what this means when we look at different schemes for organizing the curriculum. I think I can safely predict that many mathematical readers will object to the section below which deals with the organization of the curriculum, but "task-analysis" psychologists regularly make use of such devices. There needs to be some sort of meeting of the minds on this important matter.

10. The Lack of an Orienting Framework or Paradigm. Thomas S. Kuhn, in his fascinating book The Structure of Scientific Revolutions[7], provides some compelling insights into the nature of human understanding. Kuhn divides the history of science into roughly two kinds of periods: periods of relative stability, and periods of drastic revision of fundamental ideas. The periods of relative stability he calls "normal science", and the established orthodoxy of vocabulary, equipment, methodology, assumptions, and so on which constitute a relatively stable world-view he calls a paradigm. Possibly revising Kuhn's analysis somewhat, I should like to argue for the occasional existence of what might be called "locally-stable paradigms". Thus, electricity in the days of Benjamin Franklin knew three "locally-stable paradigms": the view that electricity was basically a "fluid" that "flowed" through "conductors"; the view that electricity was basically an active force, similar to but different from gravity, and generated by friction; and the view that focused on repulsion together with attraction as the fundamental electrical phenomena.[8] Each tradition built its own characteristic kinds of apparatus, designed its own experiments, explained them in its own characteristic way, and developed its own set of concepts, definitions, and assumptions.

From these three separate "traditions", "paradigms", "schools", or "orthodoxies" there ultimately emerged a single all-embracing paradigm, which therefore superseded the three partial paradigms:

> Only through the work of Franklin and his immediate successors did a theory arise that could account with something like equal facility for nearly all these effects and that therefore could and did provide a subsequent generation of 'electricians' with a common paradigm for its research.[9]

Similarly, the parallel existence of "particle" and "wave" approaches to light is well-known; and the diverse early interpretations of oxygen provide a particularly illuminating example which Kuhn treats at some length.

Enlarging somewhat on Kuhn's usage, we might say that paradigms come in all sizes, from something as small as a self-consistent philosophy of one man to something as large as a system of orthodox belief and orthodox practice shared by an entire generation of scholars. Probably for, our present purposes in education, we can make do with more-or-less "medium-sized" paradigms. I don't hope to rope Bruner, Rogers, Koch, and Skinner under one umbrella, but we can hope for a reasonable consensum provided we pick our participants carefully enough.

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[7] University of Chicago Press, 1962.

[8] Kuhn, op. cit., p. 14.

[9] Kuhn, op. cit., p. 15.

Now Kuhn makes several things quite clear about paradigms. Most important is the fact that, in the absence of a viable paradigm, you cannot make significant intellectural progress by the processes of "normal science". (I think the same remark extends also to the useful study of art.)

Kuhn gives many examples that show clearly that "mere facts" in the absence of a paradigm get you nowhere. For example:

> If we can accept a considerably broadened use of the term 'rule'--one that will occasionally equate it with 'established viewpoint' or with 'preconception'--then the problems (Kuhn uses the word "problem" in a rather specific technical sense, something like "an approved exercise".--RBD.) accessible within a given research tradition display something much like...(the characteristics of a puzzle, such as a cross-word puzzle or an end-game in chess.) The man who builds an instrument to determine optical wave lengths must not be satisfied with a piece of equipment that merely attributes particular numbers to particular spectral lines. He is not just an explorer or measurer. On the contrary, he must show, by analyzing his apparatus in terms of the established body of optical theory, that the numbers his instrument produces are the ones that enter theory as wave lengths. If some residual vagueness in the theory or some unanalyzed component of his apparatus prevents his completing that demonstration, his colleagues may well conclude that he has measured nothing at all. For example, the electron-scattering maxima that were later diagnosed as indices of electron wave length, had no apparent significance when first observed and recorded. Before they became measures of anything, they had to be related to a theory that predicted the wave-like behavior of matter in motion. And even after that relation was pointed out, the apparatus had to be redesigned so that the experimental results might be correlated unequivocally with theory. Until those conditions had been satisfied, no problem had been solved.[10]

As a second example:

> ...X-rays provide a classic case of discovery through accident, a type that occurs more frequently than the imper-

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[10] Thomas S. Kuhn, op. cit., pp. 38-39.

> sonal standards of scientific reporting allow us easily to realize. Its story opens on the day that the physicist Roentgen interrupted a normal investigation of cathode rays because he had noticed that a barium platinocyanide screen at some distance from his shielded apparatus glowed when the discharge was in process. Further indications--they required seven hectic weeks during which Roentgen rarely left the laboratory--indicated that the cause of the glow came in straight lines from the cathode ray tube, that the radiation cast shadows, could not be deflected by a magnet, and much else besides. Before announcing his discovery, Roentgen had convinced himself that his effect was not due to cathode rays but to an agent with at least some similarity to light.
>
> ...Roentgen's discovery commenced with the recognition that his screen glowed when it should not. ...the perception of anomaly -- of a phenomenon, that is, for which his paradigm had not readied the investigator--played an essential role in preparing the way for perception of novelty. But... the perception that something had gone wrong was only the prelude to discovery. ...X-rays did not emerge without a further process of experimentation and assimilation. At what point in Roentgen's investigation, for example, ought we say that X-rays had actually been discovered? Not, in any case, at the first instant, when all that had been noted was a glowing screen. At least one other investigator had seen that glow and, to his subsequent chagrin, discovered nothing at all. Nor, it is almost as clear, can the moment of discovery be pushed forward to a point during the last week of investigation, by which time Roentgen was exploring the properties of the new radiation he had already discovered. We can only say that X-rays emerged in Würzburg between November 8 and December 28, 1895.[11]

In the operations of most schools, and the design of most curricula, we do not in fact have the advantage of possessing a moderately viable paradigm. In its place we have only chaos and mindless empiricism. Working within such a framework, we cannot assemble enough "understanding" to let us make wise decisions.

Consider, for example, this discussion of the way schools often treat Indian children who have been brought up within their own tribal culture:

> Unlike the adult models of the slum child or the migrant, those provided by the reservation setting are not merely the more or less arbitrary socializing agents who quite unwittingly acculturate the children away from mainstream society; on the contrary,

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[11] Kuhn, op. cit., pp. 57-58.

> Indians tend to make a special effort to indoctrinate their offspring in tribal ways, and to cultivate tribal loyalty at an early age. In other words, Indian children are quite deliberately socialized in the traditional culture, and this process often ingrains in the child a different view of his future from that held by a middle-class white child. Thus, from the start of his formal education, the average Indian child has at best a severely limited perception of the larger American community, and he is likely to be wholly unprepared for its vastly different cultural orientation as it is explicitly presented by the American school.
>
> The problem of conflict that results in severe. On the one hand, the Indian child's whole socializing identity has been formed by the tribal culture; on the other, his attendance at school represents entry into an entirely different culture. The tug of war between his tribal orientation and the orientation of the school poses severe identity strains of the Indian child. If he moves toward the institutional orientation he may be viewed as trying to be a white man; if he accepts the tribal orientation he limits his mobility in the mainstream society. Adding to this conflict is the fact that the school, as an institution which reflects the mainstream orientation, is often insensitive to the values inherent in Indian culture. For example, when Indian children enter school they are told that they may no longer speak their native tongue. Many schools have passed a rule making English the only acceptable language. What educators have in essence been saying to the young children is, "We disapprove of your parents, your people, and everything you have been able to do with your language. We're going to teach you another language that from now on you must use. Many educators now believe this has done much more harm than good.[12]

This seems to me to show the result of paradigm ambiguity: no particular paradigm (or partial paradigm) has been available (or, in any event, has been used) to organize our efforts and to inform our decisions. Consideration of the child's self-concept? His sense of identity? His feeling of mastering over the environment? His achievement? His reading level?

Granted that one perhaps sees a paradigm or a partial paradigm emerging in the Fantini - Weinstein analysis, one nonetheless gets (quite accurately, I'm sure) the impression that most school decisions are not related to "normal science", or to any other use of a self-consistent "paradigm" or carefully - worked - out "school of thought".[13]

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12. Mario Fantini and Gerald Weinstein, The Disadvantaged: Challenge to Education, Harper and Row (1968), pp. 67-68.

13. It may be precisely because most schools have no developed paradigm whatsoever (but rather rely upon a deliberately ambiguous and defensive electicism) that those few schools which do possess articulated paradigms of some sort stand out so markedly--as, for example, the Montessori Schools, or the Dalton School, do.

The reference to Louis Smith and William Geoffrey, cited earlier, shows this absence of a "tradition" or "rationale" or "paradigm" even more clearly. Instead of any organized approach to understanding what the school is trying to do, we see must schools operated on the policy of a desperate struggle to stave off catastrophe for as long as possible.[14]

While I realize that the profound subtleties of Kuhn's book may seem far removed from the immediate tragedies of today's slum classroom (or, for that matter, from most suburban classrooms), I think Kuhn deserves careful study. How could Scheele or Priestley or Lavoisier decide that they had discovered oxygen when they had no system (or at least none that we would accept today) for classifying chemical substances? How can we deal more creatively, more humanely, with our children if we have no articulated theory for analyzing knowledge, children, learning, teaching, and the organizing of each of these?

11. The Need for Diversity. Education has failed to recognize the absence of an "organizing theory" of "paradigm". But if one looks at the matter more closely, education has also failed to recognize the need for the simultaneous existence and development of a number of different and competing paradigms. We cannot all set out to build "a good school", all of us working from the same unarticulated, unexamined, bland assumptions. Each of those investigators who studied electricity belonged to one of three possible schools of thought. Those who studied oxygen could build on either the phologiston interpretation (as Priestley did), or else on the "caloric" and "principle of acidity" conceptualization (as Lavoisier did).

The need for the simultaneous pursuit of different paradigms in education is, nowdays, crucial. This becomes clear when one contrasts the open-ended exploration of the Elementary School Science (E.S.S.) units with the linearly - organized small-step "task analysis" approach of the Oak Leaf School's "Individually Programmed Instruction" (I.P.I.).

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[14] Obviously, I do know some good schools. If I have seemed to malign them I apologize. But the average school does not provide a suitable environment for learning. The evidence for this claim is overwhelming, and, what is perhaps the sorriest part of the picture is not simply a low "mean" performance, but the fact that the "standard deviation" for all schools is incredibly small. One school (with the few exceptions already mentioned) is very much like another. Cf., for example Daniel P. Moynihan, "Education of the Urban Poor", Bulletin of the Harvard Graduate School of Education Association, vol. XII, No. 2 (Fall, 1967), p. 5: "This, I believe, is what Coleman says: not that schools have no effect--a preposterous notion--but rather than, by and large, given the vast educational system of the United States, they appear to have surprisingly similar effects". As Moynihan remarks elsewhere, Coleman tells us (for the most part) what careful and honest observers of schools have known for a long time. As one visiting British scientist once asked: "Where are your good schools?"

I want therefore to call attention to Appendix A of the present N.S.F. proposal excerpt. The "initial" and "national" category (p. 13 of the excerpt) suggests that we must "identify a cadre of scientists - mathematicians - educators with inquiry approach philosophy".

This is virtually the first time that I have seen initial project planning, for any project, concern itself explicitly with the selection of a specific school of thought or "paradigm". Presumably the paradigm will be articulated, scrutinized, and modified--but it has not been left unrecognized.[15] Conceivably a better, all-encompassing paradigm (such as Mendeleev's) may be found that will supercede our present partial paradigm. But at least we have taken one step toward removing educational actu-analysis from the status of revealed truth (which in fact it never actually had), and have moved instead toward the usual manner of human discourse in any sophisticated and serious subject.

Other people will choose other paradigms. Excellent! We wish them well. But presumably we shall try to integrate our development of curriculum units, our teacher education, our operation of schools and classrooms, and our invention of educational theory in a self-consistent way, so that we are attempting to articulate a definite paradigm. We are not, as so often happens, seeking security in the works and crannies of ambiguity. We shall not, as has so often happened, allow ourselves to sink into a turbulent sea of conflicting goals, inconsistent operational strategies, and unrecognized inconsistencies. Our own observations certainly confirm the remarks of Moyniham and Coleman referred to earlier: most schools are like nearly all other schools (just as most teacher education programs are like nearly all other teacher education programs), and they share an ineffectuality and a blandness that prevents any program from doing very much for most children. Perhaps the door which will allow us to escape from this ubiquitous homeostatic ineffectiveness is precisely the selection of a specific paradigm and a commitment to it. If I understand correctly, the present NSF - Kansas State Teachers College proposal plans precisely this kind of commitment to an "inquiry" paradigm.

Perhaps I should add that this matter of a deliberate selection of a definite paradigm is not innocuous: It means that we have to modify our modus operandi, our theoretical framework, and our data collection procedures so as to be consistent with the paradigm we choose. One could not get very far with an "inquiry" paradigm in the school which Jonathan Kozol describes, nor in the Inidan schools which Fantini and Weinstein describe. Nor can one presume to use a common method of "evaluation" for different paradigms. To do so would make no sense at all.

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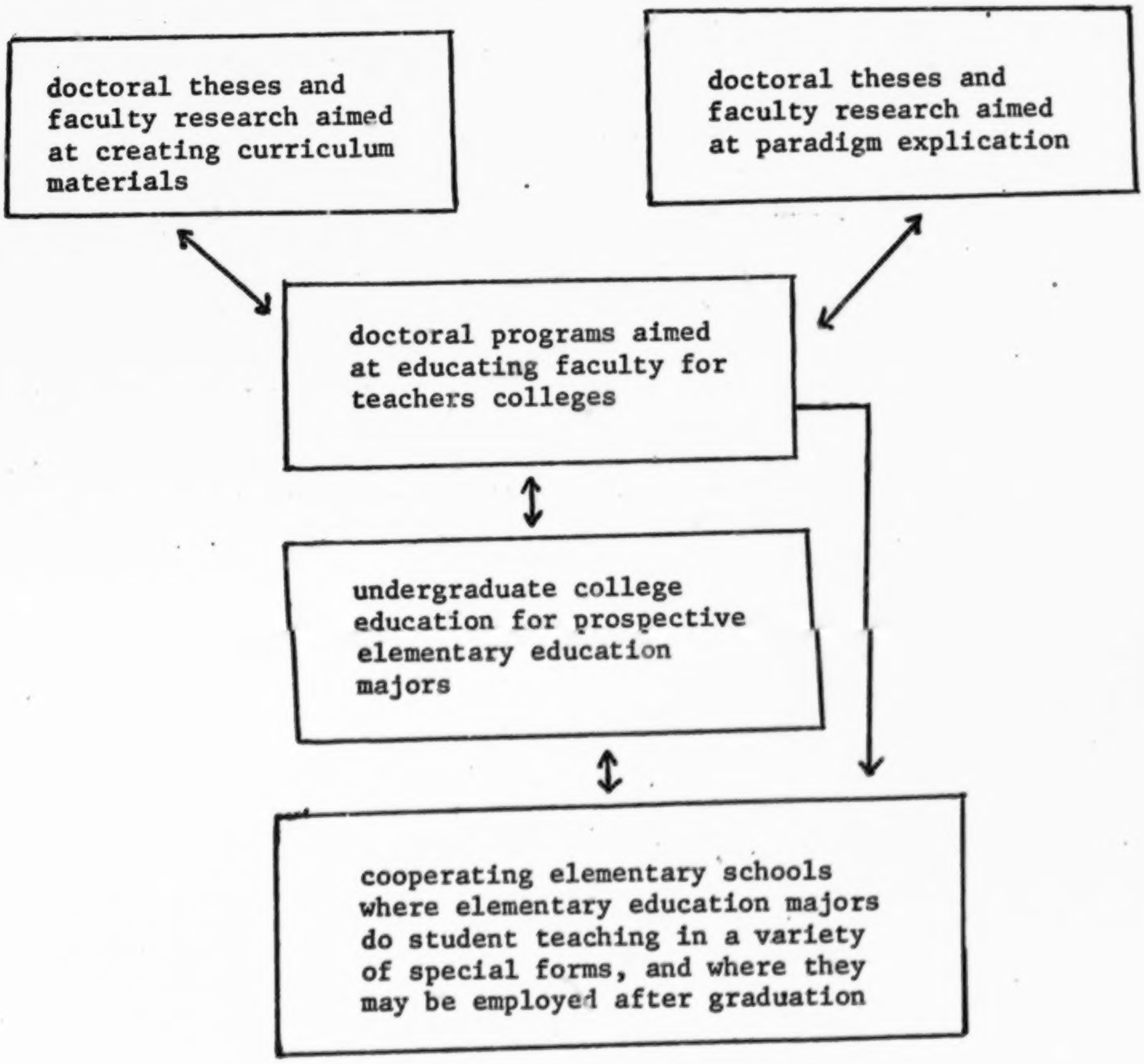
15. Max Beberman, David Page, and the AAAS programs would all be justified in taking exception to my claim that this is the "first", probably they are right. However, recognition that we do not possess a universal paradigm and must therefore settle for selecting a partial paradigm that we believe in seems to me to be carried a step further forward in the present proposal.

12. The Absence of a 'System' Approach. Admittedly, the phrase 'systems approach' has recently become a clique, and one hesitates to use it just at present, but it does have a reasonable meaning, and this is the meaning we want to call forth. A minimum effective "system" is about what is described in the Emporia proposal. Diagrammatically, it looks about like this:


doctoral theses and faculty research aimed at creating curriculum materials
doctoral theses and faculty research aimed at paradigm explication
doctoral programs aimed at educating faculty for teachers colleges
undergraduate college education for prospective elementary education majors
cooperating elementary schools where elementary education majors do student teaching in a variety of special forms, and where they may be employed after graduation

What is important is that all of these components share enough of a common paradigm so that they can work together effectively.

Possibly one needs to add two further components:

a curriculum/pedagogy innovation and development facility, such as E.S.S., E.S.I., E.D.C., the Madison Project, MINNEMAST, etc.

a specific dissemination facility, which would respond to requests from non-participating schools, etc.

I shall not bother to indicate interconnections among all of these "boxes"; we presume that the interconnections exist.

II. Organizing Schemes

In this section I want to present descriptions of some of the methods presently used in organizing

the learning experiences
the children
the adults
the resources

in various elementary schools. I include this material neither to argue for various schemes nor against them (although I find I cannot remain entirely neutral), but because many people have not raised some of the necessary questions, and I think we shall all be better off if we do raise them. As E. H. Vause, Executive Director of |I|D|E|A| said recently,

> ... [Most schools have not kept pace with a changing society.] The same philosophical attitudes toward students persist, the same teaching methodology is in evidence everywhere, and even much of the so-called new curricular materials have been designed to be used in conventional ways..
>
> The tragedy of all this is that it need not be so. [16]

It will continue to be so, however, unless we all take somewhat broader looks at what is (or should be) happening to elementary schools and to teacher education. There is a third element here that is often overlooked, namely, the "conventional wisdom" of different scholarly groups, the common conceptualizations of education, and the operating hypotheses that determine what happens in schools.

Here are some of the presently-proposed methods of organizing curriculum, people, and resources:

1. Organizing the Learning Experiences. In outline form, I propose that we look briefly at the following organizing strategies:

    A. The linear "task analysis" "no-choice" model

        i. Variation 1: What degree of achievement is required to exit from a unit?

        ii. Variation 2: What provision is made for student choice?

        iii. Variation 3: What provision is made for student initiative?

        iv. Variation 4: Shall we introduce a smaller "step size"?

        v. Variation 5: What provision is made for individual differences?

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[16] Tom Kasper, Summary Report of a National High School Youth Conference on Education (mimeographed; available from |I|D|E|A|, P. O. Box 446, Melbourne, Florida 32901)

vi. Variation 6: What other devices are used to provide for "exiting" from a unit?

B. Gagné-type "hierarchical" models

C. "Gestalt" or "analytical" models

D. E. S. S. - type exploration models

i. How much effort is made to extract specific "rules"

E. The "massive readiness" approach

F. The "topic-extension" approach

G. The "project" approach

H. What risks are involved in the use of the various preceding models?

This, roughly, is what I mean:

The Linear "task analysis" "no-choice" model. In this curriculum arrangement, all of education is usually broken up into a collection of specific student performances that are to be elecited by specific signals. For example, the printed "problem"

$$\boxed{\begin{array}{lr} \text{Add:} & 24 \\ & 13 \\ & 19 \\ & \underline{26} \end{array}}$$

might be identified as a signal, intended to evoke from the student the specific behavior of writing "82" in the appropriate place:

$$\boxed{\begin{array}{lr} \text{Add:} & 24 \\ & 13 \\ & 19 \\ & \underline{26} \\ & 82 \end{array}}$$

Obviously, we cannot be quite this specific, for if we focused on this addition problem, teaching "addition" would be an unnecessary complication. It would be far more efficient to teach children that whenever they saw something like

$$\boxed{\begin{array}{lr} \text{Add:} & 24 \\ & 25 \\ & 19 \\ & \underline{51} \end{array}}$$

or anything generally resembling this visual pattern, they should write "82" and, if only the original problem were ever used as stimulus material, merely writing "82" would in fact constitute a "correct" response.

Much of this undoubtedly sounds like a crazy way to think about education, and if we use this kind of methodology badly we shall, indeed, be working according to a gigantically inappropriate notion of education. This is precisely what worries me.

But to continue: suppose, the, we broaden this, not to merely the specific problem

Add: 24
13
19
26

but rather to an equivalence class (as it were) of all problems involving adding four numbers, each of two digits.

This is one specific "behavioral outcome".

In a similar way, we list all of the "behavioral outcomes" for our entire course of study.

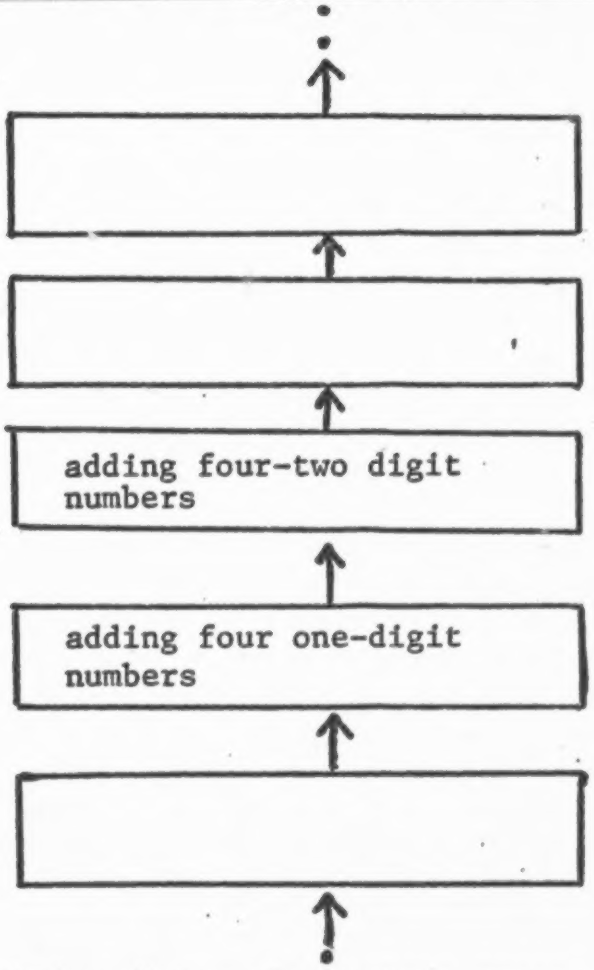
Now, in order to achieve a well-determined curriculum, we must arrange all of these different "behavioral outcomes" in some sort of order. It is at this point that we may choose to adopt the "linear " "no-choice" model.

The following example will show what this means.

Presumably, for instance, we have on our list also a "behavioral outcome" labeled "the ability to add four numbers, each having one digit only."

It is not hard to see that this one-digit addition should precede the two-digit addition problems, because in fact the actual act of solving a two-digit addition problem makes use of the devices of adding a one-digit problem.

Hence, we can arrange our behavioral objections in a strict linear form, first one, then the next, then the one after that, and so on. Diagramatically, we could write



This is called "linear" for the obvious reason that it is a linear arrangement in the ordinary sense. It is called a "no-choice" sequence since at no point does the student get his choice of what to do next.

We could use such an arrangement, and I know of schools that do.

But this method does not seem likely to be able to cope with all of education. Indeed, in the view of some of us, it seems unlikely to be able to cope with more than a very small part of education.

For one thing, while it is sometimes reasonable to expect behavior A to precede behavior B, in many cases there is no reason whatsoever to prefer one order to the other.

For example, which operation should come first: addition, subtraction, division, or multiplication? We may someday have some defendable reason for a preference, at least for a special class of students, but at present we do not. Some people--for example, Beryl Cochran--who have studied the problem have found division and subtraction to be the most natural for very young children, because of experiences in sharing with siblings, or consuming a portion of some finite resource, such as a box of candies.

In such cases we may use a linear order, if we want, but we cannot claim (as some do) that it is "based on scientific evidence". In fact, it is a decision based on the preference or intuition of the curriculum designer.

Even among those who are attempting linear curriculum arrangements, there are many unresolved questions, for example:

a) It is common to require 90% master, or better, before moving on to the next unit. Many teachers consider this unwise, and would prefer to move on to the next unit--i.e., to "exit" from the present unit--when the child achieves something of the order of 30% mastery. They can cite considerable experience in their favor; if a child can count "reasonably" well, how long do we want to hold the child to the task of relatively dull "counting" before we move on to more interesting tasks that make use of counting?

Indeed, should we perhaps turn the whole affair around, as the British often do, and begin by "making use of counting"--indeed, by imbedding "counting" into such a natural framework of activities that the child never perceives himself as "counting" or "doing arithmetic"? Rather, he is "collecting milk money" or "taking attendance" or "keeping score".

Further, suppose a child is not achieving a great enough reliability to "graduate" or "exit" from the present task. What do we do with him? Keep repeating this failure? Move to other activities that don't depend upon this particular skill? Move back to something easier? (In our own work we find that, for some children, it is preferable to move ahead to something "harder" or "more advanced". David Page has also reported success with this same strategy.)[17]

b) The strict linear model gives the child no choice. Obviously, we could give the child many opportunities to make his own decisions: to ask for easier problems, or harder ones; to drop temporarily a task with which he has become bored; or having finished a unit successfully, the child could elect to continue in this direction, or to drop it for the time being.

Most of the other variations suggested in our outline are probably largely self-explanatory. "Provision for student initiative" is obvious, though to my knowledge it is rarely present in curricula organized in even semi-linear fashion. The obstacle, obviously, is that it is difficult--and probably impossible--to know in advance what children will suggest.

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[17] The phrase "for some children" is crucial. One great complication in educational research at present is that we have no adequate taxonomy of children nor of "types of failure to perform." Creating such a taxonomy has been crucial for political science, where it is known that a given political act will be viewed differently by rich than by poor, by white than by black, by Protestant than by Catholic, by "hawks" than by "doves". We do not know the corresponding categories in education. Fantini and Weinstein, for example, refer to the case of American Hopi Indian children who deliberately give wrong answers in order not to embarass their classmates (Fantini and Weinstein, op. cit., p. 86; see also p. 91); we ourselves have found this same behavior among some girls in classes in Africa. Obviously, to diagnose this behavior as "misunderstanding" or a "cognitive error" would itself be an error.

We have had a third grade boy invent an algorithm for subtracting:

$$\begin{array}{r} 64 \\ -\underline{28} \\ {}^{-}4 \\ \underline{40} \\ 36 \end{array}$$

by making use of negative numbers. (None of the adults present had ever thought of this possibility before.)[18]

We've had seventh-graders propose that we study

$$x^2 + ky^2 = 25$$

for negative values of k by using the 2-by-2 matrices isomorphic to the complex numbers.[19] A ninth-grade girl used matrices to solve

$$x^2 = 2,$$

and a different 9th grade girl used the intersection of a parabola and a straight line to argue for the existence of a number whose square is two. A seventh grade boy took P. S. S. C. tape-dot "velocity" ticker-tape and converted to the standard unit of inches per second by feeding the ticker-tape through the tape-transport unit of an audio tape recorder with a known speed of 7 1/2 i.p.s.

How will a "mechanical" curriculum organization provide for this? Yet student initiative on this level of quality, sophistication, and originality occurs very commonly, both among privileged and underprivileged children, provided the school atmosphere encourages it (which it very rarely does).

(Cf. also the discussion of infinite regions in the plane, initiated by some 8th graders in a class in Webster Groves, Missouri.[20] Who on earth would have anticipated this?)

Let me turn to a far more "mechanical" question. Where and when should we switch to a smaller "step" size? For example, we have considered Task B:

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[18] Robert B. Davis, "Math Takes a New Path," The PTA Magazine, Vol. LVII, No. 6 (February, 1963), pp. 8-11.

[19] This lesson, fortunately, was being recorded, so you can view the result yourself on the Madison Project film entitled Graphing an Ellipse.

[20] Cf. Robert B. Davis, "Mathematics for the Middle School:, in: Mauritz Johnson, ed., Four Academic Subjects in the Middle School Years, available from the School of Education, Cornell University, Ithaca, N. Y. (1967), pp. 51-54.

Add 4 numbers, of two digits each. We also considered Task A: Add 4 numbers of one digit each.

Are these too broadly defined? Should we consider Task A_1: Add 4 numbers of one digit each, with no "carry" into the tens place?

i.e., something like:

Add: 1
2
2
2

Should we distinguish this from Task A_2: Add one-digit numbers, where a "carry" to the tens place does occur? i.e., something like:

Add: 3
7
9
2

We might even want to consider an intermediate task, Task $A_{1.5}$, where the "size" comes in early, and the subsequent "increments" are small, as in:

Add: 5
2
2
1

Similarly, "Task B" might be decomposed into a kind of "hyper-fine structure", as in Task B_1: Add 4 numbers of 2 digits each, with no carries, such as:

Add: 21
12
11
10

and, perhaps, Taks B_2, with no carries to the tens place, but a carry to the one-hundreds place, and where the "size" comes in early and the "increments" are small:

Add: 71
12
11
10

Task B_3 might involve a carry to the tens place, but none to the hundreds place, and again having the "size" come in early and the increments be small:

Add: 16
11
13
12

The reader can easily add his own versions of Task A_n and Task B_m for any desired values of n and m. How finely should we discriminate? *And for which* *students*?

Notice, moreover, that we now lose any logical determination of a linear order (although empirical data might provide some answers--again, presumably, for *some* specific categories of children). The problem

Add: 21
12
11
10

does not *logically* depend upon "carrying" at all, and could perfectly well come *before* the problem

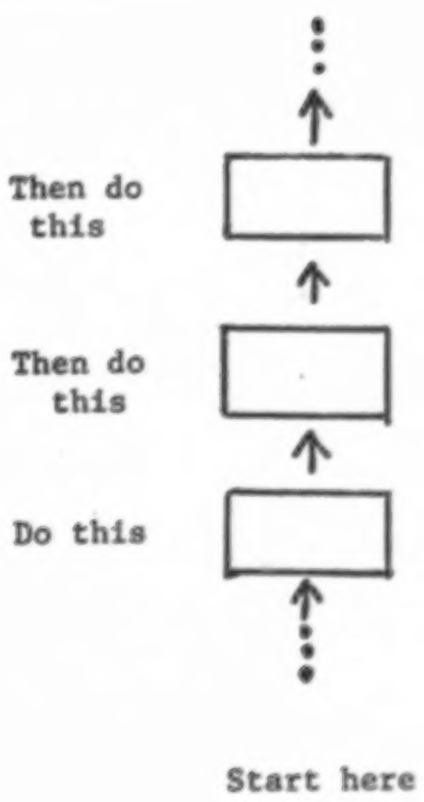
Add: 7
3
2
2

Patrick Suppes is presently getting a large amount of data on this particular dimension, by using computer-assisted facilities. Such an approach does not, however, transcend paradigms. It is (as one would expect) research *within* a specific paradigm, and leaves us still with the unresolved question of alternative paradigms. (This is particularly true because present work usually uses response time, or error rate, as the criterion of "success"; yet it is by no means universally accepted that the goal of education is the rapid production of error-free responses in a highly restricted stimulus situation.)

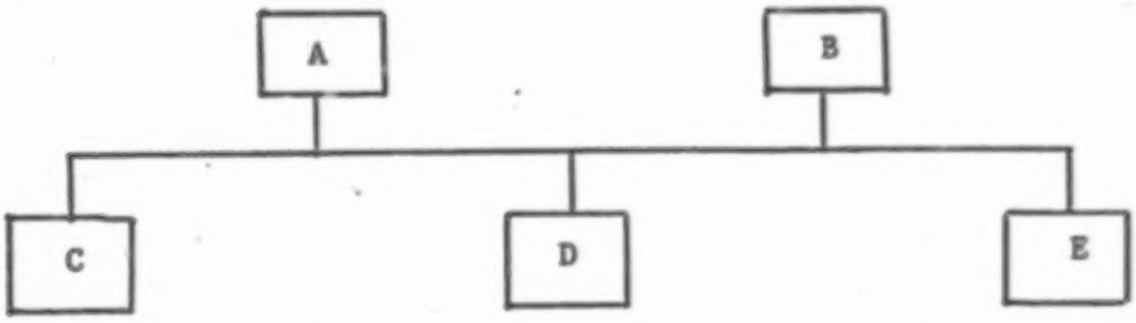
Perhaps later refinements of "semi-linear" or "pseudo-linear" curriculum sequences may distinguish several categories of experiences: for example, concrete experience with grouping (as in the traditional "rubber-bands around tongue depressors" approach); *visual* as well as tacile experiences (on this same concept of place-value numerals; experiences in mathematical depth (as in writing the "polynomial" form of numerals); experiences in using the ideas in some very natural (if you will, "childish") context; and so on. One would then need some theory to order *types* of experiences as well as "topics" or "tasks". Again, the reader can easily see for himself that we are approaching chains that threaten to become as complex in their possible variety, as DNA sequences.

While much more could be said about linear or nearly-linear sequences, let us turn to some alternative organizational principles:

Gagné - type, or "hierarchical" sequences. These sequences, associated with (among others) the names of Robert Gagné and Lauren Resnick, seem to me to be different from the linear sequences we considered above. Perhaps the initial identification of "behavioral objectives" is similar, but whereas a "linear" sequence is in fact a linear array



The hierarchical array looks more like an organization chart or a family tree



where "behavior A" would depend upon a mastery of behaviors C, D, and E (but not necessarily B,) and "behavior B" would similarly depend upon C, D, and E, but not upon A.

Thus a student automatically has choices.

He may begin with C, or D, or with E, or, if he prefers, he may work on C, D, and E simultaneously (or in any order he chooses). Having achieved some level of mastery of C, D, and E (and here, again, there is disagreement as to what this level of mastery should be), the student would be free to move on *either to A, or else to B.* Thus there is much more apparent student choice. Despite this apparent choice, the student is ultimately led through the same sequence of learning experiences.

One variation on this scheme is to specify *terminal* "behavioral objectives" for each stage, *but not to specify the learning activities themselves*. In this sense, the "curriculum" becomes a hyperfine net of "examinations" (like a Regents Exam every three minutes), but what happens *between* the "exams" is left entirely up to each individual teacher.

As a *practical* approach this variation may in fact be a good idea, but as a "scientific" approach it is indefensible--for a reason that haunts us again and again" the "same" terminal behavior for two different students may not actually *be* the same at all!

A student might write

Agricola aquam portat.

because he has practiced writing it over and over again, even though he knows nothing of the meanings of the words, nor of the rules of Latin grammar. Another student might write this same sentence as a Latin translation of the English "The farmer carries water."

If we look only at *what the student did*--that is, at his final producation--in either case we see

Agricola aquam portat.

But the actual *behaviors* were entirely different even though *the ultimate productions were the same*.

Worrying about this is not being fanciful. If I were allowed one single criticism of both *schools* as they usually operate, and also of the *conventional wisdom of educational theory* today, it would be: *We identify and pursue specific products of behavior, but we ignore the actual behavior itself.*

This point is so important that I want to present one or two examples:

1. We have just considered the Latin example;

2. It comes up frequently when students memorize a particular proff in geometry so that they can write it down, even though they would never have conjectured the theorem, could not have worked out a strategy for creating an original proof, and quite possibly don't understand what they have written. They can, however, produce the written "product"--from memory.

3. It appears, similarly, whenever students solve equations by factoring them, because they have memorized this procedure, without understanding that they are depending upon the non-existence of "divisors of zero".

4. It appears whenever students memorize the truth table for

[illegible]	Q	$P \Rightarrow Q$
T	T	T
T	F	F
F	T	T
F	F	T

without considering possible alternatives, without considering the ordinary language uses of "If P, then Q", and without asking *why* this particular assignment of truth values has been made, and over how large a domain of human behavior it is appropriate. (It is *not* universally appropriate if we really mean to study human uses of "If P, then Q".)

5. It appears whenever we fail to distinguish between a behavior product which we have somehow specifically elicited, as opposed to the "same" product volunteered as an original creative production by the student, produced through original internal mental interactions within his own cognitive schemata.

6. It appears, in fact, whenever we conceptualize learning (or testing) in a "stimulus-response" mode, *without minutely scrutinizing the entire "stimulus" over the individual's entire past history, insofar as this* may be relevant. A genuinely impromptu and unprepared joke is not the same as one concocted in advance and saved for use on the proper occasion, or even one devised by a team of script writers, even though the *words* may be identical. To confuse the two may not always have dangerous *practical* consequences (although in education it seems to), but it is *always fundamentally wrong from a* scientific or epistemological point of view.

7. This error has been so common, and has so thoroughly destroyed school mathematics, that there are literally hundreds of examples and counter-examples available to us. We shall consider only two more: first, there is the highly elaborate theory of Basil Bernstein and others, which forms a foundation for a long discussion in Fantini and Weinstein.[21] This theory is *not* compatible with a "product" orientation. Here is a brief instance:

> When a mother who utilizes a restricted language code disciplines her child, there is apt to be less talking through of acts, less verbal investigation of motives. Whereas one mother is likely to explain the rule and place it in context verbally--"No, Johnny, don't hit your little brother; you'll hurt him."--another is likely to announce the rule and leave it at that "I've told you, you don't do that![22] You know I've told you to leave your brother alone!"

Now, both mother behaviors (presumably) achieve the same immediate result: Johnny (presumably) stops hitting his little brother. Therefore, to "product"-oriented theorists, both mothers have done the same thing. But to Bernstein, Fantini, and Weinstein the two mothers have done quite different things. *We do not agree upon our* "equivalence classes" of behavior.

8. As a final example, we have asked some psychologist of the "task analysis" school to consider what Pythagoras did in investigating the question of whether there did exist a number (i.e., a rational number) whose square is 2. There are several highly important steps here which they have been unable to fit into their conceptualization of what it is to "do mathematics". For one things, Pythagoras asked a question which no one had ever asked before, and which there was no reason for anyone to ask--no reason, that is, as long as one accepted the conventional wisdom of mathematics at that point in history. For another thing, in the usual proff, one comes

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[21] Fantini and Weinstein, op. cit., Chapter 3 ("The Language of the Parent as Teacher").

[22] Fantini and Weinstein, op. cit., p. 109.

3. We know of many cases of 7th graders making their own original movies; indeed, there are now festivals and awards for films made by children. Many of these movies are extremely original. (One shows the viewer how gyroscopes work, and--more or less-why. The student who made it is not considered particularly creative in school, in the opinion of his teachers. He made the film outside of school. His parents say of him: "Life, for him, begins at three o'clock.")

4. This powerful legitimate creativity has been observed repeatedly by Hughes Mearns[23] (junior high children writing original poetry of genuine professional caliber that is now often included in ordinary "adult" anthologies, with no concession to the youth of the authors); Herbert Kohl[24] (similarly, with culturally-deprived children writing powerful original poetry); Jonathon Kozol (cf. the excerpt from Kozol's book[25], quoted earlier); and is commented upon also in Fantini and Weinstein:

> Another student teacher, assigned to Harvard's Operation Second Chance in a Boston junior high school, wrote of her pupils' "not 'gramatically" correct" compositions:
>
> > .....But several [compositions] have the telling quality of some of the folk songs and spirituals we studied. Some would seem to reflect the compassion and awareness of reality that Reynolds' story stirred within them. All were written with verve and without apprehension.
> >
> > I think it is David Holbrook, the British poet and educator, who says that the creative efforts of such children may be compared with the artist's impulse that forges a work of literature....I know....that the writing of these compositions represent an expression of themselves not unlike very real artistic creations.
>
> Significantly, this teacher found that even the more enlightened teaching methods in which she had been trained had not prepared her adequately to meet the reality of these children, and "reflect our general unreadiness to adjust education programs in ways radical enough to meet the real needs and nature of such children."[26]

The Kozol and Fantini-Weinstein quotations should establish that schools fail because they are trying to do the wrong thing. They do not need more efficient methods of pursuing their present goals; they need to adopt a new set of goals.

A further example from Herbert Kohl deserves consideration:

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[23] Hughes Mearns, Creative Power. Dover, New York, 1958.

[24] Herbert R. Kohl, Teaching The Unteachable. The New York Review, 1967.

[25] Kozol, op. cit., (refer to page 9 of this paper).

[26] Fantini and Weinstein, op. cit., pp. 89-90. The quote is from: Gail Donov "The 'Lively Art' of Language", Harvard Graduate School of Education Bulle vol. 10, no. 2 (Summer, 1965), p. 11.

SHOP WITH MOM

I love to shop with mom
And talk to the friendly grocer
And help her make the list
Seems to make us closer.
--Nellie, age 11

THE JUNKIES

When they are
in the street
they pass it
along to each
other but when
they see the
police they would
run some would
just stand still
and be beat
so pity ful
that they want
to cry
--Mary, age 11

Nellie's poem received high praise. Her teacher like the rhyme "closer" and "grocer," and thought she said a great deal in four lines. Most of all the teacher was pleased that Nellie expressed such a pleasant and healthy thought. Nellie was pleased, too, her poem was published in the school paper. I was moved and excited by Mary's poem and made the mistake of showing it to the teacher who edited the school newspaper. She was horrified. First of all, she informed me, Mary couldn't possibly know what junkies were, and, morever, the other children wouldn't be interested in such a poem. There weren't any rhymes or clearly discernible meter. The word "pityful" was split up incorrectly, "be beat" wasn't proper English and, finally, it wasn't really poetry but just the ramblings of a disturbed girl.

My initial reaction was outrage--what did she know about poetry, or about Mary? But it is too easy to be cruel about the ignorance that is so characteristic of the schools today. That teacher did believe that she knew what poetry was, and that there was a Correct Language in which it was expressed. Her attitude towards the correctness of language and the form of poetry was in a way identical to her attitude towards what sentiments good children's poems ought to express. Yet language is not static, nor is it possible a priori to establish rules governing what can or cannot be written any more than it is possible to establish rules governing what can or cannot be felt.

Not long ago when I was teaching a class of remote, resistant children in a Harlem school, as an experiment I asked these children to write. I had no great expectations. I had been told that the children were from one to three years behind in reading, that they came from "deprived" and "disadvantaged" homes and were ignorant of the language of the schools. I had also been told that their vocabulary was limited, that they couldn't make abstractions, were not introspective, oriented to physical rather than mental activity. Other teachers in the school called the children "them" and spoke of teaching as a thankless military task. I couldn't accept this mythology: I wanted my pupils to tell me about themselves. For reasons that were hardly literary I set out to explore the possibilities of teaching language, literature, and writing in ways that would enable children to speak about what they felt they were not allowed to acknowledge

> publicly. Much to my surprise the children wrote a great deal; and they invented their own language to do so. Only a very small number of the children had what can be called "talent," and many of them had only a single story to write and rewrite; yet almost all of them responded, and seemed to become more alive through their writing.
>
> ...
>
> I have subsequently discovered other teachers who have explored language and literature with their pupils in this way, with results no less dramatic. The children we have taught ranged from the pre-school years to high school, from lower-class ghetto children to upper-class suburban ones. There are few teaching techniques that we share in common, and no philosophy of education that binds us. Some of these teachers have tight, carefully controlled classrooms; others care less for order and more for invention. There are Deweyites, traditionalists, classicists--a large range of educational philosophies and teaching styles. If there is anything common to our work it is the concern to listen to what the children have to say and the ability to respond to it as honestly as possible, no matter how painful it may be to our teacherly prides and preconceptions. We have allowed ourselves to learn from our pupils and to expect the unexpected.[27]

What does all of this have to do with mathematics? The relevance could hardly be clearer. Children think about mathematics just as creatively as they do when they are writing poetry--provided we allow them to do so. Most schools attempt to tell mathematics to children, and they fail. They fail not because they do a poor job of the telling. They fail because doing mathematics, like writing poetry, is not a story that can be told. It is a craft to be mastered by emulation, speculation, participation, trial-and error, and reflection--processes which most schools discourage.

I digress because I think that the conventional wisdom of education is a trap, and one which we must struggle to escape. As long as we think about schools in conventional ways, we will not successfully improve the learning of mathematics, or science, or anything else.

But let me return to an example of a hierarchical curriculum arrangement of the Gagné-Resnick type. Suppose we want to teach children to count. Successful counting depends upon at least three skills:

For one things, we must be able to say the names "one", "two", "three",... in the correct order. This is a basic skill, and appears also in the need to be able to say "Monday, Tuesday, Wednesday..." in the correct order. or "A, B, C,..." or "January, February, March,...". Call this Task α.

Then, also, we must be able to synchronize certain motions or perceptions with the pronunciation of one-syllable words. (To make this independent of Task α we do not require these words to be "one, two, three...") Call this Task β.

Yet, again, we need some skill at "systematic bookkeeping", so that if (say), we are counting pebbles, we can keep track of which ones we have counted and which ones we have not yet counted. This task can also be made independent of the preceding tasks if this is desirable, since we could, for example, be "keeping track of which pebbles we have touched with our finger". Call this Task γ .

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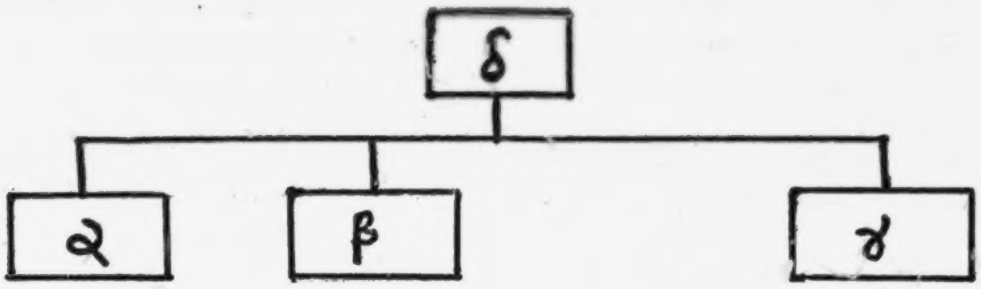
[27] Kohl, op. cit., pages 11-13

If we arrange the three preceding tasks so that they are independent of one another, and if we teach them before we actually try for the combined skill of accurate counting, then we have a diagram like this:



where δ is the task of actual counting.

Is it better to begin with such preliminary skills? It is better to arrange (as we can) to have the preliminary skills independent of one another? Is it a correct assumption that, once a child has mastered tasks α, β and, γ, he is ready to tackle task δ ? Is it better to immerse the child in an environment where tasks α, β, γ and δ are all more or less simultaneously present--to try for what Roger Brown has called "massive readiness"? Is sequential task analysis better than massive readiness followed up by specific "diagnosis" of weak spots and by specific "therapy" for them? What implications do these various approaches have for optimal school organization? What long-term effects will they have on children?

There is much more that needs to be said about this, but time and space limitations prevent it.

By way of contrast, we mention the idea of "gestalt" or "analytical" experiences, where a "large" task comes first--"How many cars pass by the school in ten minutes?"--and as this task is undertaken by a group of children they try to develop such subsiding skills as they find necessary. This approach is often used in England today.[28]

There is also the "exploration" experience used as a curriculum foundation. Particularly fine examples of this are provided by the elementary school science units developed by the E. S. S. project at E. D. C.[29] The E. S. S. - type of exploratory learning experience is very different from the Gagné-Resnick approach, and it is hard to see how we can encompass both within a single conceptualization of education. If we cannot, then presumably we cannot consider the question of "which is better?"

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[28] Refer to four Featherstone articles, Nuffield booklets, NAIS pamphlet, and the film I Do...and I Understand (full references given in bibliography).

[29] See, for example, "Gases and Airs" by Paul Merrick; the butterfly unit developed by Emily Richard; the spider unit also developed by Emily Richard; units available from the Webster Division of McGraw-Hill include: Structures (1968); Sand (1968); Crayfish (1968); Geoblocks (1967); Pond Water (1967); Balancing (1968); and Balloons (1968). See also the film entitled Classrooms in Transition, available from Mary Lela Sherburne, Education Development Center, Inc., 55 Chapel Street, Newton, Massachusetts, 02158.

I have discussed elsewhere the "topic-extension" approach to curriculum design, and merely list it here.[30]

2. Ways of Organizing the Children. If you have between 300 and 3,000 children in a school, you must also somehow "organize" them. Recent curriculum work has been very traditional in its approach to arrangements of children; must commonly it has assumed an arrangement by grade levels.

This does not appear to be the best way to arrange the children; the question is important because curriculum experiences and arrangement of children are closely interrelated. Suppose, for example, we want a 6-year-old (or so) to get experience making change: "changing" a quarter to two dimes and a nickel, etc. If we want each child to do this, many times, and to do it correctly, we probably want one teacher per child. Now, we can easily have one teacher per child, if we have a room containing 10 six-year-olds. A ten-year-old can work, one-to-one, with a six-year-old on the task of making change.

Such a classroom requires two curricula: one, the "curriculum to be learned", and the other the "teacher training program" for the older children. (Of course, the older children also have their own "curriculum to be learned".) This arrangement is not necessarily used all day long, but it can be.

I know schools, at present, using the following methods of arranging children:

A. By grade level, with random assignment of children within grade levels ("heterogeneous grouping").

B. By grade level, where a given room contains either a "middle ability group" and a "low ability group", or else a "middle ability group" and a "high ability group" (this is sometimes called the "cluster" system).

C. By grade level, where (say) all fifth graders are divided into three separate groups, the "highest ability group", the "middle ability group", and the "lowest ability group". (This is usually called "homogeneous grouping" or "tracking" in the United State, and "streaming" in England.)

D. Departmentally, where a specific group of children is assembled for reading, a different specific group for science, etc. (In short, this elementary school organization rather resembles that commonly used by colleges.)

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30. Cf. Robert B. Davis, United States Office of Education Final Report, 1967.

E. "Small-group" organization within the classroom: in this arrangement, there are (say) 30 children in the room, but they are divided into 10 "teams" or "committees", with 3 children per committee. Committees work independently of one another. (This can be seen on the English film I Do..And I Understand; available from: Radim Films, 220 West 42nd Street, New York, New York 10036. Also available from Mr. S. Titheradge, Manager, New Print Department, Sound Services, Ltd., Wilton Crescent, Merton Park, London, S. S. 19, England.

F. "Individualized instruction". In this system, the teacher moves around the room, working with one child at a time. Different children are therefore not necessarily reading from the same textbooks, etc., and may be working at different grade levels.

G. "Continuous progress": This really refers more to the organization of the learning experiences, rather than the organization of the children, but is usually thought of in the latter terms. If this is coupled with a graded classroom, and small-group or individualized instruction within that classroom, it means that committess or individuals move ahead at their own pace. The room may be called "fourth grade", but some committees or individuals within the room may be working on "second grade" materials, or on "seventh grade" materials, or whatever is appropriate for them.

H. "Ungraded schools": I used to think I knew what this meant, but at present I do not. It is different from the following two arrangemnets:

I. "Family-plan" classrooms. Here, within one room, we have (say) a few six-year-olds, a few seven-year-olds, a few eight-year-olds, and a few nine-year-olds. This arrangement appears to be getting excellent results in England, and is even[31] in use at present in my own neighborhood in Syracuse, New York.

J. "Skip-grade" classrooms: Here one has (in one actual case) ninth grade children spending part of their schoolday teaching seventh grade children, while other ninth graders spend part of their school day teaching second grade children. This is somewhat similar to a "family-plan" classroom, but does not use consecutive age groups. Instead, it mingles children whose ages differ by a larger amount.

K. "Ad Hoc" improvised mixtures of the preceding arrangements: for example, in one school with a "three-track" program, the top-track fifth grade and top-track sixth-grade occasionally meet together for mathematics lessons. (This school is also departmentalized, so these "tracks" are determined on the specific criterion of mathematical ability.)

There are coming to be equally diverse ways of allocating the adults (teacher aids, para-professionals, parent assistants, team leaders, specialist teachers, etc.) which I can't really go into at present. But we must keep these new patterns in mind, or else our "new math-science curriculum" will in fact be hopelessly old-fashioned.

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[31] Cf. Clarence C. Anderson, "Experiment at Sumner", Empire Magazine, Syracuse Herald-American, Sunday, June 2, 1968, pp. 1-5.

III. Some Theorems

Of course these aren't really "theorems". They are intended as succinct statements of some of the main points I am trying to make.

Theorem 1. The elementary school and the curriculum. A school probably does demand that the adults, the children, the learning experiences, and the resources be organized in some way. In general, professional mathematicians have preferred not even to think about this question. Yet is needs to be faced, and more flexible means of organizing the curriculum need to be worked out and somehow put into actual practice, together with more flexible ways of arranging the children, the adults, and the various resources.[32]

Theorem 2. Organizations and programs. The time has indeed come when it makes sense to take a "systems" approach, and to fit together modified teacher education programs, modified elementary schools, curriculum innovation work, educational theory, in-service and "advanced " teacher education programs, and programs of advanced study by the faculty of teachers' colleges. Specifically, I propose a group of such institutions, sharing a common philosophy, working together. It makes no sense to have a university's undergraduate teacher education program unrelated to curriculum innovation and at that same university. It makes no sense to graduate new teachers who must immediately begin the study of contemporary programs because their own undergraduate training did not in any way prepare them for contemporary programs.

Central to the task of fitting these pieces together is something like the curriculum innovation project, on the model of E. S. S., MINNEMAST, UICSM, or the Madison Project. Practically none of these projects (except perhaps UICSM and MINNEMAST) seems to have achieved organizational stability. This is regrettable and should be remedied. A curriculum innovation group is a new kind of organization in education. At its best, it posseses more flexibility, more effective quality control (particularly where personnel are concerned), a greater committment to articulating a paradigm (instead of merely concealing the absence of any paradigm whatsoever), a greater committment to innovation, and a greater openness to new ideas and to the contributions of newly-appearing personnel (especially talented young people) than most educational organizations do. This new kind of organization is needed in education. How to retain its openness, committment, and flexibility while at the same time giving it greater organizational stability is actually one of the most important problems, and deserves serious attention immediately while we still have the present organizations around as models. (How is vigor and innovativeness maintained in some sectors of industry?)

Theorem 3. Educational Theory. We do not, today, have an "umbrella" conceptualization of education which embraces all of the present approaches and important ideas. We must recognize parallel (you might say "separate but possibly equal") paradigms. A given venture should commit itself to a

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32. Although the study was at the high school level, many of the innovations have suggestions or actual parallels at the elementary school level. Consequently, it is interesting to cf. Gordon Cawelti, "Innovative Practices in High Schools: Who Does What--And Why--And How", Nation's Schools, April, 1967. A special reprint is available from I D E A, P. O. Box 446, Melbourne, Florida.

definite paradigm, conduct its educational programs within that paradigm, develop its theory within that paradigm, and assess its results within that paradigm. We need more than one paradigm.[33] That, in turn, means we need more than one coalition of institutions.

At this point (and several others) the Emporia proposal worries me: how shall we achieve enough internal philosophical consistency to be effective, without closing the door to the development of alternative paradigms?[34] (Of course, competing ideas may, or may not, involve competing institutions.)

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[33] Nobody ever gives up a paradigm or belief because it is a bad idea, or an inadequate one. You can't beat something with nothing. Kuhn (op. cit., p. 8) points out: "Competition between segments of the scientific community is the only historical process that ever actually results in the rejection of one previously accepted theory or in the adoption of another."

[34] It may seem that I am overly worried about this. The actual history of science largely justifies my worry. Cf. these remarks by Kuhn (op. cit. pp. 89-93): "Almost always the men who achieve these fundamental inventions of a new paradigm have been either very young or very new to the field whose paradigm they change. And perhaps that point need not have been made explicit, for obviously these are the men who, being little committed by prior practice to the traditional rules of normal science, are particularly likely to see that those rules no longer definite a playable game and to conceive another set that can replace them.

...Like the choice between competing political institutions, that between competing paradigms proves to be a choice between incompatible modes of community life. Because it has that character, the choice is not and cannot be determined merely by the evaluative procedures characteristic of normal science, for these depend in part upon a particular paradigm, and that paradigm is at issue. When paradigms enter, as they must, into a debate about paradigm choice, their role is necessarily circular. Each group uses its own paradigm to argue in that paradigm's defense.

The resulting circularity does not, of course, make the arguments wrong or even ineffectual. The man who premises a paradigm when arguing in its defense can nonetheless provide a clear exhibit of what scientific practice will be like for those who adopt the new view of nature. That exhibit can be immensely persuasive, often compellingly so. Yet, whatever its force, the status of the curcular argument is only that of persuasion. It cannot be made logically or even probabilistically compelling for those who refuse to step into the circle. The premises and values shared by the two parties to a debate over paradigms are not sufficiently extensive for that. As in political revolutions, so in paradigm choice--there is not standard higher than the assent of the relevant community. To discover how scientific revolutions are effected, we shall therefore have to examine not only the impact of nature and of logic, but also the techniques of persuasive argumentation effective within the quite special groups that constitute the community of scientists."

Operational Level	Operation (Short Range) 1-3 years	Financing or other Activity
National	Initially: Identify a cadre of scientists-mathematicians-educators with inquiry approach philosophy and establish a project administration	**NATIONAL SCIENCE FOUNDATION**
Regional	Develop regional personnel and regional project centers. Organize to conduct teacher training sessions by using workshops or work sessions of 3 to 5 days in length	**NATIONAL SCIENCE FOUNDATION**
Regional or state	Select key elementary personnel from school systems and cross train in science and mathematics using structural approach to mathematics and relate to science. Two consecutive summer sessions (5-6 weeks) plus inservice sessions during academic year	**TITLE III OR IV ESEA**
School District	Key personnel (minimum of 1 per 30 classes K-6 work with other teachers at the teacher's own level. The key person has at least 1/2 time free for helping other teachers plan and implement their teaching of math and science. The key teacher is a special teacher of science and math, not a supervisor or coordinator.	**SUGGEST THE KEY TEACHER MIGHT BE SUPPORTED PART-TIME ON TITLE I ESEA**

Operational Level	Operation (Long Range) 3-10 years	Financing or other Activity
National	Standing Curriculum Committee at U. S. Office of Education supported by an office position for elementary mathematics and science specialists	A FUNCTION OF THE U. S. OFFICE OF EDUCATION
State	One or more elementary school mathematics and science specialists per state determined by school populations K-6.	A FUNCTION OF THE STATE DEPARTMENT OF EDUCATION-DIVISION OF INSTRUCTION
School District	One or more elementary school mathematics and science specialists or coordinators (minimum; one per 90 elementary school classes of 20-30 pupils each) K-6	A FUNCTION OF THE SUPERVISING OR COORDINATING OFFICE OF INSTRUCTION
School Building	One or more special mathematics and science teacher (like music, P.E., etc.) per school (Minimum: one per 10 classes) K-6	HIRED AS PART OF TEACM OF PROFESSIONALS TO TEACH IN GRADES K-6. WOULD USE MULTISENSORY AIDS AND PROGRAMMED INSTRUCTION IN ADDITION TO LABORATORY INSTRUCTION. EACH SCHOOL SHOULD HAVE A MATHEMATICS-SCIENCE LABORATORY

Theorem 4, Don't underestimate the philosophical difficulty. The teaching or learning of science and mathematics probably does make certain demands upon teachers and schools. In particular, they probably do in fact demand:

exploration
flashes of insight into new possibilities
a "rhetoric of inquiry" rather than a "rhetoric of conclusions" [35]
tentativeness instead of absolutes
a recognition of the possibility of never-ending modification and refinement

These are difficult demands for many teachers and schools to cope with, or even for many educational paradigms to conceptualize.

Theorem 5. Don't underestimate the organizational difficulty. There is something about an organization that does not love flexibility, that does ~~exalt form~~ over content, that is neutral if not inimical to serious commitment and purpose, that is not open to innovation, that is not open to maximum contributions from newly-discovered talented young people, and that more often fosters destructive competition or apathy rather than genuine creative cooperation. Thus one of our problems is how to work constructively with the "establishment", while yet building on the "Peace Corps" spirit.

Education does not give enough opportunity and responsibility to talented, creative young people.[36] If we cannot rememdy this, we probably cannot improve education very much.

(Mozart once wrote to his father: "They pay me too much for what I do here, and too little for what I could do.")

(In the United States Sentate, Robert F. Kennedy's seniority was 99th.)

IV. Specific Comments on the Emporia Proposal

Since I plan to comment on it, let me reproduce here Appendix A of the Emporia Proposal:

Comment 1: p. 13, "National Level". The suggestion of a commitment (presumably a flexible one) to a specified paradigm ("with inquiry approach philosophy") seems to me to be excellent. Presumably some effort will be expended on articulating this particular philosophy.

Comment 2: p. 13, "National Level". The phrase "establish a project administration" worries me. We do not want a monolithic national institution that can protect its paradigm by political means rather than by rational means.

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[35] Possibly the best essay on this subject--indeed, an excellent one--is, J. J. Schwab, "The Teaching of Science as Enquity", in J. J. Schwab and Paul Brandwein, The Teaching of Science. Harvard University Press, 1964, pp. 1-103.

[36] Cf. especially, The University Game, Adelman and Lee, editors, Anansi, Toronto, Canada, 1968.

There are several ways out of this dilemma. One is by way of competing institutions (in the present case, competing consortia), which follows in part the pattern we have today. We have SCIS, CCSM, ESS, MINIMAST, AAAS, MADISON PROJECT, UICSM, SMSG, etc. None of these, to the best of my knowledge, has had much effect on contemporary wisdom of educational theory, and to this extent they have all failed at the tasks of paradigm articulation. (I apologize to any project that feels it has succeeded. But don't talk to too many educators, or you may begin to wonder...)

Another would be by creating a sequel to CCSM which would emulate some of the form of the United States government. It would be representative, so that UICSM, SMSG, Madison Project, etc., could choose their own representatives to this national board, by their own methods. There would be provision for new comers to "gate - crash", so that the national board would not be a closed corporation. Following the pattern of the Supreme Court, it would render its decisions in the full light of written professional records, with opinions supported by argumentation, with signed opinion, with dissenting minority reports (also signed), with "letters to the editor", etc. It would thus be open to newcomers and to new ideas.

The format of this written record would be a marked departure from common present tradition, in that it would not be ritualistic. It would have neither a prescribed format nor a prescribed style (A good example of what I consider the "right" way to do this would be the Journal of Research in Science Teaching, as edited by Dr. J. Stanley Marshall. Many different forms of dicision making, explanation, and paradigm articulation--as well as simple reporting--are contained in the journal.)

Comment 3: p. 13, "Regional Level". I recommend this highly. It is essentially the way that the Madison Project operates itself, although the Madison Project is too small to be efficient, and one should surely operate on a larger scale.

Comment 4: p. 13, "Regional or state level". Certainly something of the sort described here is necessary. But notice that this is one more curriculum that has to be created. Our studies of "summer institute" type programs have shown them to be generally ineffective, although they are popular both with secondary teachers and with college faculty, since they provide a convenient form of summer employment. Meanwhile, back at the school, these institutes do not produce any dramatic improvements in classroom teaching that we can observe. We have to create more effective teacher education curricula for "6 week summer programs".

We also have to select participants more effectively. Here, too--although it will be politically difficult--we must include talented, creative young people, and we must open up some doors for them when they return to their own school system. (The same applies to talented, creative people who are not young.)

The idea of using "2 consecutive summer sessions plus an academic year program"--I presume for the same participants--is excellent. Most "new curriculum" work has been mere tokenism. We spend 12 years in precollege education, four years in college, turn out an ineffective teacher, and expect to remedy this with one 6-week program.

Clearly the alternatives are either to select teachers who are already effective as inputs for our program, or else to have much deeper programs--or, preferably, both. We keep underestimating the difficulty of this task.

Comment 5: p. 13, "School District Level". "The key teacher is a special teacher of science and math, not a supervisor or coordinator".

This is an excellent idea! As I have attempted to argue elsewhere,[37] we have hardly ever taken seriously the art of teaching as an art. We need to work much harder to identify superior practitioners and to let others learn the art from them. Instead of doing this, in the past we have tended either to theorize (which has been relatively unproductive) or to bureaucratize (which is positively detrimental).

Comment 6: p. 13 A, "National" Level. Obviously, what is proposed here worries me. It may be exactly what we need. But we must realize that we are doing the same kind of thing that Americans did when they wrote the constitution and created our government. If we shape the organization with a lack of vision, or we fill the positions with mediocre incumbents, we will be in trouble. If we aren't worried about this, it can only be because we don't understand the implications of what we are doing.

Comment 7: p. 13 A, "State" Level. What is proposed here deserves the same remark as the immediately preceding matter.

Comment 8: p. 13 A, "School District" Level. Now I know we have gone wrong. This is positively bureaucratic in the worst sense of the word. I shall be amazed if this is not a recipe for mediocrity--and it is the routine, inflexible organization that is at fault.

The number of people hired should be a function of the number of talented people available. American public schools have achieved their present homeostatic mediocrity in large measure by making the incorrect assumption that the number of people hired should be a function of the need. This, coupled with ineffective training programs and inadequate leadership, has been enough to produce the present state of affairs.

(I am not really arguing with the authors of the proposal. I suspect they would exercise good judgement. But they may not be making the decision.)

Comment 9: p. 13 A, "School Building" Level. Somehow here I am not worried, especially if we can make curriculum and pedagogy an honorable craft, as it is in parts of England, rather than a combination of semi-skilled labor and artificial sophistication, as it often is within the United States. I have faith in creative teachers, even if I have my doubts about educational theorists.

It would be possible to comment on the Emporia proposal at great length, but time forbids it.

Suffice it to say that there are three things that convince me of the necessity for a systems approach, such as is proposed here:

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[37] Robert B. Davis, Journal of Research and Development in Education, Monograph number 1(Fall, 1967), Athens, Georgia.

i) I know a very few good elementary schools, and a vast number that range from mediocre to bad.

ii) I know a sizeable number of talented people--mostly, but not all, young people--who have been seeking out satisfactory doctoral programs where they can earn a doctorate, while growing professionally to a significant degree. Most of these people claim that they can't find appropriate programs anywhere they have looked, and I believe them.

iii) I know universities from living inside them, and I consequently know that in general they have no real sense of mission, and that their internal organization would stand in the way of pursuing a worthwhile mission if they ever found one.

That all adds up to this: we've got to do something soon!

Appendix a

Alternative Organizational Schemes

1. The British Nuffield Mathematics Project establishes "centers"--each center is a suite of several rooms, mostly in a school that is not filled to capacity--to which teachers may come for seminars, self-study of new curriculum materials, to view films, to check out materials for use elsewhere, etc.

One could carry this one stage further and provide each center with a professional staff of "innovations in curriculum and pedagogy". This is essentially the system used in Japan for high school biology.

At one higher level of escalation, a center could include residential facilities, so that a group of teachers could come and stay for a week or two. By now you have a curriculum adaptation of what some U. S. universities call a "Center for Continuing Education" (e.g., the University of Chicago and the University of Georgia have these, not restricted, however, to elementary school curriculum and pedagogy).

2. The Sumner School in Syracuse hopes to have all of their teachers present during the month of August, for a special faculty education level. Such an arrangement is not uncommon. The fact that it is a concentrated local effort is in its favor: no sensible school will tool up for a program they do not intend to implement. But this, by itself, is not the ultimate answer, either. Individual local schools usually lack any real depth of subject matter knowledge, and are usually not really au courant regarding innovative programs. Thus a well-intentioned effort easily degerates into the blind leading the blind.

One answer is to strengthen curriculum innovation projects, such as UICSM, ESS, MINNEMAST, etc., with adequate staff and other facilities so that they can send out teachers to help conduct these local workshops. This strikes me as excellent, but thus far no one has been willing to put up the necessary financial support for the "responsive" component of the curriculum innovation project.

3. The Madison Project is a joint effort of the participating schools and the curriculum innovation project. Thus it seems to me to be closer to the Emporia proposal than either of the two preceding schemes.

4. Some people are optimistic about working entirely "within the establishment"--e.g., you never send in specialist personnel from outside (except perhaps in very minor ways, as for a one-day conference), you leave all planning in the hands of those who are presently doing it, etc.

5. Demonstration schools. This idea is already in use. A school uses "curriculum A", and you go there to see it (or perhaps lessons are shown over broadcast TV).

Criticisms of the Various Approaches

1. The Nuffield-type centers have this weakness: If we get the diversity I personally would like to see--many *different* math (or math-science) projects--then presumably most or all of these different projects would have their own "chain" of Nuffield-type teacher innovation centers. This is like a network of competing restaurant chains: Howard Johnson vs. Savarin vs. White Tower. Will this competion be advantageous or harmful? Further--how will we guarantee that the "innovation centers" *continue to be innovative*?

2. Local school programs building on a "responsive" component of innovative projects. The dangers here seem to me to be in the area of quality. Will we over-schedule Project personnel so that they can no longer be creative? Isn't there also a danger that local schools will plan programs that are too small to be effective? (Is a four-week workshop in August, by itself, enough?) From running a Project that *has* tried to assist in such local ventures, I know that it is expensive *if* you try to do it well, and somebody will have to pay for this. (For example, how long will a gifted teacher lead a peripatetic life, helping out in various schools all over the country, and thus largely separated from his family? This ultimately comes down to money, one way or another--for example, maintaining a large enough Project staff so that no single individual has to be out "on the road" too much of the time.)

3. The joint venture: the main problem here is the virtual inevitability of *compromise*. After all, like marriage, this arrangement is a *joint* venture. There is, at present, also the fact that, since curriculum projects for the most part lack stability, the personnel who work on the *Project* side of the joint venture lack job security.

4. Working entirely within the establishment: as long as the same people are making the decisions, they will make mainly the same kind of decisions. It isn't only *money* that has been lacking; it's also been *vision* and *imagination*.

5. Demonstration schools: this is a good approach. Cf. the Oak Leaf School in suburban Pittsburgh, or the Elk Grove Schools in suburban Chicago. The usual problem is to *create* a demonstration school. If you can actually do that, you're in motion. Thereafter it becomes relatively simple to rotate other personnel through this school--some studies have shown that most innovations have been spread by the movements of people who had previously taught in schools where the innovations were in use. One can also use film, closed circuit TV, videotape, and broadcast television to let more people view the demonstration school, in as close detail as you wish.

Appendix b

What Would You Actually Teach To Teachers?

1. At the undergraduate college level (i.e., for prospective elementary school teachers), we ourselves are working on a single educational experience that combines

   A. what used to be a "methods" course

   B. what used to be separate mathematical content courses

   C. study of contemporary curriculum materials (e.g., ESS units, Nuffield Project materials, etc.)

   D. an emphasis on using manipulatable physical materials in the mathematics class

   E. actual direct work with elementary school children.

We presently believe this should be a single integrated experience. (I don't call it a "course", because I hope university education in the future will provide things other than "courses" as these are now usually conceived. But I must admit that, for the present, our own arrangement is classified as a single course sequence, arranged as 3 one-semester courses of three credits each. A group of undergraduates who begin their studies with Professor X will ordinarily continue with him for all three courses, so that the "unification" is real, not apparent.)

We feel strongly that college faculty must integrate mathematical content with actual school experiences for young children. If we leave this "integrating" task to college undergraduates and to practicing elementary school teachers, it won't get done.

By analogy, university faculty have had to develop molecular biology. If they had offered only separate programs in biology, chemistry, and physics, and had left it for the undergraduates to relate these, the progress of molecular biology would have been very much slower, indeed.

But the moment that you do try to carry out such an integration, then

A. departmental or college barriers tend to get in the way (although we ourselves have been relatively lucky thus far)

B. the conventional wisdom of the behavioral sciences becomes important.

That is why I have placed so much stress on organizational questions, and questions about the conventional wisdom. It becomes quite important whether you think first of B. F. Skinner, or Jerome Bruner, or Jean Piaget, or Roger Brown, or Harry Levin, or Richard de Charms, or J. McV. Hunt, even though mathematicians do not ordinarily think of any of these.

2. At a deeper level of commitment Webster College has attempted to take the same philosophy described in item A, and extend it to 30 credits of coursework in mathematics (rather than 9 credits), plus some additional credits in coordinated courses in physics and biology and art, with great emphasis on student initiative and with the college students spending time working in elementary schools (especially in culturally-deprived areas). This program graduates elementary school mathematics specialists.

3. Probably most effective of all has been the extension of this approach to a 30-credit M.A.T. program at Webster College. All 30 credits are labeled as "mathematics" or "physics", but great stress is placed on the question: what would you do, here, with (say) a ten-year-old child? (This program has been developed under the leadership of Professor Katharine Kharas.) The program graduates elementary school mathematics specialists.

4. Obviously, each of the preceding three programs needs its *own* curriculum. We must create up to ten *new* "courses" *for teachers*, which will be closely related to, but different from, the new courses for children.

If one follows the philosophy I am trying to suggest, these new "courses" *will not resemble what we usually think of as "mathematics" courses*. The college students will be spending time figuring out how a desk calculator works, helping para-professionals set up a "math lab" for children, working with Cuisenaire rods, observing and critiquing films of actual mathematics lessons, and working directly with young children, as well as graphing functions, making statistical studies of frequency of letters of the alphabet and of different makes of automobiles, and proving that $(A + B)^2 = A^2 + 2AB + B^2$.

Appendix c

Specific Remarks About the Emporia Proposal

The proposal states certain questions, some of which are reproduced here, with comments.

Q 1: What are the necessary relationships that should be found to exist between elementary school science and mathematics?

Remarks: In the first place, an experimental program in a culturally-deprived school in St. Louis is being developed by Webster College, with (as they say) "virtually no mathematics for its own sake appearing in the earliest grades. For younger children, the emphasis is upon science".

How this will work out remains to be seen. The underlying educational philosophy emphasizes a child exploring his environment with increasing care. (Again, that old question of the conventional wisdom of education confronts us here.)

Secondly, and more importantly, there is no easy answer to this question. I would mistrust anyone who claimed that there is. A very large number of details have to be worked out before we can even be sure what we are talking about. This calls for a much bigger effort than is presently being made.

Q 2: Is it possible to train or retrain the elementary school teachers of the nation so that modern math and science programs will become living realities for children?

Remark: This doesn't depend only on teachers. It depends also upon the school in which the teacher works. I know quite a few teachers who could do this right now, but not in the schools where they are presently employed.

On the other hand, I am not optimistic about what per cent of present teachers will ever be able to help children really learn science and mathematics, or much of anything else. Don't take my word for it. Go see for yourself.

Q 3: What should be the plan of attack if it is desirable to upgrade the level of instruction pupils are receiving in science and mathematics at the elementary school level?

Response: For one thing, the creation of several consortia of the type I describe seems to me to be essential. These would combine experimental schools, curriculum innovations facilities, teacher education programs, advanced degree programs, scholarly research, and dissemination facilities.

For another, the creation of relatively stable and adequately financed "curriculum innovation groups" (such as Nuffield, ESS, MINNEMAST, etc.), seems to me to be essential. Very few, if any, of these projects are presently large enough, or stable enough, or adequately financed.

The involvement of private industry may also help, although I am not sure about this. (At present, of course, no private industry maintains an R & D facility comparable to E.S.S.)

Q 4: Are there now in existence college and university personnel who could provide regional leadership? How can they be identified?

Response: They certainly exist. The problem is to find those who are really good, to enable those who are good to become effective, and to do all of this without exploiting these people excessively. At present, effective curriculum work is harder than "just being a college professor", and it pays much less well than either mathematical research or the writing of commercial textbooks.

Q 5: Is there a need for a national office to coordinate this effort?

Response: As I've tried to indicate, this issue scares me. Anything as big as the genuine improvement of elementary school math and science necessarily seems to acquire political ramifications. How we can avoid creating a new "establishment", that would impede further progress, yet at the same time assemble the necessary large resources worries me a great deal. We need some kind of a "Peace Corps" approach that is small enough to consider the individual classroom and the individual child, yet big enough to have an impact on a nation of 200 x 10^6 people. This is the kind of organizational problem that we have not usually solved successfully in the past.

Q 6: How can adequate manpower be developed to carry out a massive elementary school teacher training program?

Response: Frankly, I think that any massive program will be a low-quality program. I would rather see a diversity of different programs, large but not massive, and focussed more on quality than on vastness. Our school system itself has suffered from (perhaps necessarily) trying to be vast first, and good second.

I think that bona fide experimental schools are an important key to this problem--if not an essential key.

"Can We Organize The Content, The Children The Adults, and The Resources? - A Response"*

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There are two classes of problems in effecting change in the elementary, secondary and the higher schools; immediate problems and long range problems. We have found it difficult to focus on the former, because of the latter. It may well be that we will have to fix our ideas on the long-range problems and then extract short term possibilities from them.

My assignment, which I enjoyed very much, is to review for you and proceed beyond the position paper prepared by Bob Davis. As always, with his writing, I found it enormously stimulating and occasionally perplexing.

Let me review first, his major points. They seem, to me, to form a basis for discussion of long-range problems and I will take the opportunity to try to point us in what I think will be productive directions.

Bob's paper is organized into the following main topics: (a) an inventory of obstacles to change in schools, (b) organizing schemes for learning experiences and children and (c) some theorems, which are really questioning admonishments or admonishing questions. I will refer briefly to (b) and then discuss (a) and (c) in detail.

In the section on organizing schemes, Davis speaks first of organizing the learning experiences and of development of theories of instruction for learning. Finally, he speaks of ways of organizing children into a new structure to enhance the learning experience. In the latter case, he is referring to a structure that could be put together by schools. I am not going to dwell on these organizing schemes but trust the conference participants will wish to discuss them with Bob Davis later during this session.

Let me now talk a little bit about his inventory of obstacles. I will "tick" them off and comment on some of them. First, he reminds us that it is easy to give the appearance of a new curricula in math but not so easy to give the reality of it. I certainly endorse that statement but add that it probably doesn't hold quite so well for science. The reason being that there has been substantially no tradition for science instruction in the elementary school and there has been tradition for arithmetic, a part of math at any rate. Davis points out that you can add a few adjectives here and there, more modern jargon, to the existing arithmetic curriculum and it "looks" modern. You can't very well do that to a non-existing science curriculum.

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* A response to the position paper by Dr. Robert Davis. Belmont Conference, Belmont Estate, June 26-29, 1968.

His second point is that there are substantially no schools devoted to quality innovation in the United States. Now all of us obviously know of schools which are committed, devoted, to successfully carrying out innovations. The proper word to note here is the adverb "substantial". There are, after all, 93,000 elementary schools in this nation. If one accepts that one percent is "substantial" then there should be about 1,000 elementary schools devoted to innovation in this country. I would be surprised to find that this is the case. Thus, I believe it is probably a correct statement that there is substantially no tradition for innovation in the American elementary schools.

The next three points I will discuss together. The points are (1) new curricula are a challenge to the educational establishment, (2) new curricula are a challenge to the conventional wisdom of what a school is, (3) new science and math curricula ask for changes in human behavior and beliefs. The first point is, of course, abrupt. In many cases, change is difficult for all of us and therefore constitutes a challenge. The simple question occurring in a PTA meeting, "why aren't we using thus-and-so in our schools?" often, as we well know brings a defensive reaction. I think it is not difficult to understand why that should be true. It is not easy to innovate and it is not easy to change. Certainly, new curricula causes difficulty. The second point deals with the simple fact that schools are quiet places. I believe this is a perfect example of precisely what Davis has in mind. The sort of curricula most of us are talking about (contemporary curricula) are noisy as hell, which directly contradicts one of the things schools are supposed to be. The third point is that new science and math curricula asks for a change in human behavior and beliefs. Really this is a general statement of the first two. Because of the simple fact that no scientists looks at his science as authoritarian and almost everyone else in the world, who doesn't know science and math in detail, seriously views it as authoritarian; there is a contradiction from the very beginning. If we are in effect honest and realistic in science and math programs, we are simply going to have to change this view, as quickly as possible. This is asking for trouble! We are asking for a change in the beliefs and attitudes of substantial numbers of people. These three, obviously, lump together as they require profound changes that are not going to be accomplished in a three credit course in one summer term. One does not change an adult, one does not change an adolescent, I strongly suspect, in any such superficial manner. Then it certainly is not going to be changed in Friday afternoon sessions from 3:30-5:00 for a nine month period as an in-service program with teachers. We are not going to effect the kinds of changes that Bob argues need to be made in any such way. This doesn't argue against doing some of these things because we can accomplish some other things, but we should not expect to make scientists, and I don't mean professional ones either, out of elementary school teachers or out of the children by such rather modest changes in their lives.

To go on with this inventory, schools are inhospitable to children. In many examples, a number in which Bob gives, most of us do not see the kind of thing or the kind of horrible example that quite obviously exists in the United States. In one way or another, I think all of us feel the responsibility to try to correct these wrongs. I don't know that it is a particular responsibility of those concerned with science and mathematics instruction, but if we are part of society we should certainly join with any efforts to change what wrongs exist.

Next, the efforts for improvement of curricula are orders of magnitude too small. I assume that implies money, as well as, people and effort. Since it is the story of my life let it so stand. It is undoubtedly true!

Next, new curricula are not answers to recognized problems. That is, in any case the scientific and mathematics community has, for what ever reason, not developed a ground swell of feeling for the development of new curricula. In a sense, we are answering a question that we ask, but no one else did! Until we successfully plant the question in the society so that our answer is in response to a question that other people have asked we will continue to have difficulty. Those of us involved in science curricula offer an answer that by and large the population of the country has not asked. One of our jobs, in a way, is to help them ask that question, that means education. I don't mean planting the question in people's mouths, but the general cultural development which would cause the question to be asked, so the answer could be recognized, is, of course, part of the final problem. I think we are facing obstacle nine listed by Davis, that the various segments of the professions concern with education have largely ignored one another, and I am going to return to this one later. One example is that the people concerned with learning and the theories of learning, and those who are social and development psychologists have substantially no meaningful intellectual intraction with the practitioners. The curriculum builder stands in the middle with part of the *practical problems and sometimes trying desperately to look for answers in* literature on learning. It becomes very clear that there has been a divorce at one of the most crucial junctions in the development of educational curriculum that must be corrected. And you can "tick" off the others, that the mathematics department for a long time by and large has had no interaction with education and the same thing is true in science. The segments simply haven't been taught. The lack of an orienting framework or, in the language Davis uses, a paradigm. This orienting framework, I think, is his part in innovating thought which we might find useful to investigate. I do not accept it totally at the moment. One of the main offenses is the lack of orienting framework in science and mathematics. The analogy is drawn between the development of curriculum instruction in science and mathematics and the development of the great scientific models. It is argued quite persuasively, by Kuhn and others, that science really developed only through a framework suggested by some incidental ideas, a great idea in which things could be organized, in which the science involved, in which the investigators could orient themselves, suggesting new things, and so on, in structure theories. The great progress in science occurs following the occasions of the development of such an orientation framework. I accept that statement and think it true. My own concern with the analogy is that while some day we may get to a point where that is a possibility, it is dangerous to seek too soon the orienting framework or you will get oriented in the wrong direction. Frankly, I see, few indications that we know about how people learn or even about the structure of science. Mathematics is a little different. Apparently, it has a structure but tell me the structure of physics and I will bless you three times over. I spent a good part of my life trying to understand the structure. I can give you a lot of structures in physics but I cannot give you the structure in physics. I can give you a number of orienting frameworks but not one! I can give you a number of processes in science but I cannot give you one. I guess I think that it may be that my vision is not broad enough, or that the time is not yet right for the search, or the intensive search, for me to object. If some of you people can find things done in this direction I would enjoy reading and understanding them.

The next obstacle is a plea for diversity. It is a very obvious plea and we must, of necessity, keep it in the front of our minds. If we find an orienting framework, I think, I would be astonished if history showed that it was mine. In an effort to avoid any such a mistake, I think we should keep in mind the need for diversity in education. Whether it be the diversity in which children learn a thing or the diversity in which the average approach to science and mathematics is offered, we should never forget that there is a greater diversity in people than anybody would be wise enough to predict.

The final point or obstacle is the absence of a systems approach to the educational structure, as Davis and others have called it. This is certainly a heavy burden that we carry and there seems to be no clear way of designing an educational system which will effect change.

Now, those are his twelve obstacles. Let me now "tick" off and comment a bit on his theorems. I have paraphrased a number of these theorems, incidentally. Theorem one states that adults, children, learning experiences, and resources must be organized in some way. We must find some way of putting some sense into this structure by which (1) materials are provided, (2) instructions for teachers in preparation and (3) the instructional manner in which they are carried out. Rather when the hit and miss informal manner now employed some new structural organization must be evolved. Theorem two deals with higher education. Our colleges and universities must put together their teacher education program and their curriculum innovation program. On this point I will have considerable to say. Theorem three states that a given program should commit itself to a definite orienting framework and conduct its educational program within that orienting framework. But we must further correlate the theorem with more than one orienting framework for diversity. This is, in a sense, a simple-minded interpretation! This in a sense runs counter to certain traditions in education and educational research. For example, the most common example for what one does in a graduate research problem in education is what sometimes we call "horse race" type of framework. We take one orienting framework and another orienting framework, which might be the curricula, run some subjects through the two, and on some pre-post arrangements assess one in terms of the other. In effect, Davis is saying that doesn't get us very far. It would be much more useful if a full-blown development of each of the two could be made. Never mind the comparison at this point of history, perhaps both would turn out wrong, we are taking a gamble here but let's at least develop the program fully, then assess and compare. It might turn out to be a mess but we should try such an approach. Take the notions of a Karplus, just for an example, and give them the resources to develop this program. Let them develop a curriculum, build the philosophical structure, develop a teacher education program, develop schools that are using it, all consistent with that structure; but do it right! We probably have knocked off more than one good orienting framework by being able to show that children can't compute or do long division by the fifth grade and everyone should know that children should be able to do long division by the fifth grade but hardly anyone can. Therefore, whatever that orienting framework was, it was wrong and never got the chance it needed.

Theorem four: don't underestimate the philosophical difficulty in doing these things; theorem five: don't underestimate the organizational difficulty. You can see the theorems are really drawn from the obstacles that I ticked-off in the first place. These admonishments and obstacles, it seems to me, provide a jumping off point for some ideas. When I look at the educational system, I mean pre-kindergarten through graduate, and look at the complicated system, I must say that I find difficulty in approaching the problem in a rational or intellectual way. In fact, it is basically a political problem. By political, I mean the art of the possible; a search for an existence theorem. This may or may not be rational but we need possible things, not necessarily right things, just possible things to do.

Let's look at the system of institutions as a circular thing that takes in babies at one end and attempts to make from them civilized and cultural adults. Leading off from the great stream in a feedback mechanism are those who will go back to teach the next generation. We are looking at the structure and trying to find those segments most susceptable to changes. By being in higher education, I understand universities and colleges much better than I do elementary and secondary schools. I spend most of my time there and that may be why I focus on it. I would think, however, there are other reasons, than my own personal background, why we should focus there. One being the numbers of institutions and numbers of people are smaller at colleges and universities than at any other segment. That, at least, makes it possible to get in touch with a larger percent. Two, the colleges and universities contain the agents for continual change. For all its faults and difficulty that the graduate schools have caused the educational system, it contains the seeds of the ideas and development of those seeds for the next generation. There is the source of the agent for continual change. If we can be so wise as to find ways to deflect energies now generated for different purposes within the graduate department of the major universities into problems of education, we will be assured an agent for continual change in our educational system. Three, colleges and universities are the branch point in the feedback loop, where people break out and return to elementary, secondary and graduate education. Four, universities and colleges are vulnerable to change at the moment and the reason is they have the most sophisticated students of any other institution. Elementary children can't cause these changes. We need a mechanism within the university for the change we are talking about. For that mechanism, I look to curriculum development. The main thing causing change in institutions in science and mathematics education whether at the university or colleges is the effort of people who have been up to their ears in curriculum development work. This does not argue it is a unique mechanism. We need existence theorems and examples of something that causes the change. Projects supported almost entirely by the NSF have been the mechanism most obviously the source of change in the way people in higher education have behaved and in the way they have taught their courses. Although the effect hasn't been major, those people who have done curriculum development have behaved differently. It is a mechanism which I think works. Let me emphasize too, that those of you that know me, know that by curriculum development, I don't mean just material development lessons, activities, and so forth, but all the other things one does which are more important in collaborative efforts between faculty at universities and colleges in educational science, mathematics education, specialists in learning, developmental psychologist and school people. I don't mean ivory tower curriculum development but all things necessary to effect change in schools including development of materials. I don't claim this as unique. If there is merit to any of these ideas then it is necessary to change ways by which higher education is to be supported. I am concerned with changes in the view of faculty of themselves and what they do. What I purpose is a mechanism which will help them break out of this mode. I am afraid it will require basic changes within the instruction and especially in ways they budget themselves. Construction running so close, there is no investment money and this inhibits institutions to do the things I am talking about. What we need is major money to develop shops, laboratories, film and t.v. studios and space to do educational research. Second, we need operating funds to get these things off the ground. Institutions of higher learning can eventually respond to change but it usually takes five years. We can't wait that long to effect changes. We need some outside money, hopefully in short term.

I am very much an operationalist. Therefore, let me give you five operational criteria which I believe should be applied in evaluating any serious effort to get at the problems of education.

I will judge that higher education is moving toward profound solutions when any or all of the following five objectives move from the barely discernible to the readily observable.

1. We can expect progress when we observe the regular and detailed involvement of the discipline-oriented research scholar in the problem of education.

The top of our educational system continues to tolerate the circumstances whereby most of the discernible pressures on university faculty to excel and most of the rewards for excellence are directed outward from the needs of education to the demanding taskmasters of discipline and profession. It is a false image of the present university professor which does not recognize the enormous satisfactions realized from the international community of scholars in his discipline and it is a serious mistake to underestimate the effects resulting from the fact that almost all funds supporting the work for which he receives recognition come from the outside. A major task before higher education is to discover mechanisms and resources to turn a noticeable fraction of the creative energy of a faculty inward to the problems of education.

2. We can expect progress when we observe a fraction of graduate programs turn from a sole concern with the development of the discipline to problems of educational research and development.

We are evidently trapped by our rhetoric of what constitutes scholarly work as a training ground for graduate students in the disciplines. In fact a noticeable fraction of Ph.D. theses in the sciences are an important and useful recasting of old ideas for the education of other scholars in the field. It seems to me not a major deflection from high purpose to broaden this procedure to include recasting of old ideas for the education of those other than scholars in the field -- for example elementary and secondary school youngsters and college undergraduates.

3. We can expect progress when we observe the direct and important use of the research results of social and developmental psychologists in the design of instruction.

The isolation of learning theorists from the practical realities of instruction has impoverished instruction and delimited opportunities for research in this field. To the extent that a productive collaboration is developed between experts in learning and the amateurs who teach will we begin to understand why the ideas we cherish and find so beautifully simple are so hard for students to understand.

4. We can expect progress when we observe the development of intellectural leadership in the schools and undergraduate colleges.

Until the time that major decisions on curriculum and course content and educational objectives can be made with significant contributions from all levels of the educational system and to the general satisfaction of the educational practitioners at all levels, the basic decisions will be made from the top. My major thesis throughout this paper has been that the problems are much too difficult to tolerate reliance on the judgment and knowledge of so narrowly selected a group. It will only be by the development of a profound respect for intellectual achievement, broadly defined, that the potential for intellectual leadership in our schools and colleges can be exploited.

5. We can expect progress when we observe facilities and support for the regular and systematic improvement of instruction as a legitimate and ongoing responsibility of all faculties of higher education.

I do not claim uniqueness for this route to solution. Sad as it may be, the search at this moment is for theorems establishing the existence of solutions. Discussions of uniqueness of solution have no place in our present struggle toward accommodation.

If there is merit to these ideas, there is a necessary change in some of the ways by which higher education is to be supported. I am concerned with changes in the view of university faculty of their responsibilities and I propose these changes through the mechanism of projects for the improvement of educational materials and techniques. To effect the revolution will require basic changes within the institution. By the procedure of incremental budgeting (a procedure that has served universities well over the recent period of sharply increasing enrollment) it is virtually impossible to turn on major continuing programs without external help. Help is required in two areas. Major money is required for the development of laboratories, shops, film and t.v. studios to support the activities of educational research and development. I believe they should be designed and operated to be accessible to faculty from the elementary and secondary schools and from other institutions of higher education. Secondly, major resources must be made available as an "internal foundation" by which the educational leaders of the university can stimulate, according to the total needs of their responsibility, the activity in educational development required. If we are serious in our believe that university faculty are a necessary (but not sufficient) ingredient in that solution, then it is time that we seek out, as a matter of national policy, those universities anxious for change and support their efforts.

The proposed rationale of educational research and development centers follows. One hundred such centers operating with the universities in all areas of instruction to which 1% of the existing teachers go annually for a twelve (12) month period (figures to 200 teachers per center) with a staff of 25 and a budget of $\$5 \times 10^6$ per center. (Note that 1/2 billion dollars is one-half of one percent of the federal budget). This would build a system very similar to that of the Cooperative Extension idea of the Land Grant Universities, one of the truly successful educational experiments of all time.

There are, without doubt, an enormous number of symptomatic problems across the educational system: teacher education, continuing teacher education, the transfer student, research in learning and teaching, long-range planning, accreditation, on and on. But until the men and women who make up our educational institutions can discover a vital intellectural unity to their effort, the symptoms will persist. A likely candidate -- my favorite -- for this intellectual unity is a joint and continuing effort in research and development of curricular and course materials. The seeds for such a program are already germinating in some of our most respected universities. A little warm sun and some "green rain" could well produce the spirit of intellectual community so desperatley needed across higher education.

John W. Gardner has a way of finding the right words to express my thoughts. In one of his books he quotes William Hazlitt: "Man is the only animal that is struck with the difference between what things are and what they ought to be.". Whether one is given to laughing or weeping, it doesn't take much of an observer to see where we are in American education; nor does it take much of a prophet to see where we ought to be. But we do need some men and resources to take the small steps that immediately and obviously can move us toward where we ought to be.

"Effective Models for Training Teachers" *

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This paper is written with the assumption that conference participants are already convinced of the value of improving mathematics and science programs for elementary school pupils. It is also assumed that participants have a personal philosophy of education which does not clash with the contemporary (new) curricula. Consequently, the paper focuses upon methods of improving the program via teacher education.

Specific ideas are delineated when it is expected that they are needed to present a well rounded picture. Some of them are controversial, others come close to being obvious; all should be considered as points of departure. At times there are no details, just a direction. This too is necessary for a position paper, especially when there are alternate paths possible. In that context, words such as "should" and "must" should be considered as personal opinions of the writer.

What follows then are replies to questions posed in the proposal, rather than answers.

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* A position paper presented to Belmont Conference, Belmont Estate, Elkridge, Maryland. June 26-29, 1968.

(1) How can adequate manpower be developed to carry out a massive elementary school teacher training program?

There are many educators whose knowledge of science and mathematics is not being utilized to help elementary school teachers. Herein lies a primary source of manpower which needs encouragement and enlightenment more than it needs development. Who are these educators? A non-exclusive list follows: 1) academic department faculty in colleges and universities who can be convinced that they would have a meaningful contribution to make, if they would acquaint themselves with the needs of teachers; 2) education department faculty whose official responsibilities are so widespread or general that they do not have time to capitalize on a specialization they once had; 3) school administrators who once taught science or mathematics; 4) secondary school and junior college teachers who can learn about the problems of lower grades and empathize with them; 5) graduate students, in pure science or mathematics as well as education, who would obtain satisfaction from working in elementary schools on a part-time basis; 6) Peace Corps returnees looking for a place "at home"; 7) industrial and commercial personnel who are either intuitive educators or people who previously held professional jobs in education; 8) elementary school teachers. There they are. They need someone to organize a program which will acquaint them with elementary school problems and give direction and supervision as needed.

A secondary source of manpower that may be lost if they are allowed to think they aren't needed for elementary education -- undergraduate majors in science and mathematics. At present most of them would be correct if they claimed that there was no place for them to use their interests and knowledge in grades K-6. Give them a chance to do something now, as undergraduates. Let them help young children and their teachers in some small way today, and they may be key people in a teacher training program five or more years from now.

In essence the challenge is to find a group of people who now understand the science and mathematics and are willing to learn about needs of elementary schools. It is essential that they be provided with direction and time, i.e. money to relieve them of other responsibilities. The direction is to help them appreciate the attitudes and approaches inherent in contemporary curricula, the time is self-evident.

The direction which is called for can come from science and mathematics educators who are now specializing. This includes not only college and university faculty, but also personnel from school districts and related educational organizations, e.g. regional educational laboratories or research centers, curriculum development projects, publishers. Each specialist should be encouraged to direct others.

(2) It is possible to train or retrain the elementary school teachers of the nation in a fashion such that modern mathematics and science programs will reach the pupils at that level? Is it necessary?

Modern programs include more than a set of information; they try to convey new attitudes about learning and understanding. The minimal requirement for teachers is that they be open to the approach of contemporary curriculum materials and allow the students to use them in the manner for which they are designed. Even this minimal level of acceptance is not to be expected of every teacher reached by a training program, and we can not expect all teachers to become involved in training programs. We have therefore a two-fold problem, one of exposing teachers to training programs and another of influencing those we bring into these programs.

Among the problems encountered in trying to expose teachers we have a range-from the quantity of teachers to be reached, to the resistance of a given teacher. Resistance continues to be a source of difficulty even after some people are engaged in a training or retraining situation. Many of these problems will be discussed in later sections of the paper. A random list follows to give a view of the range.

A. Obstacles in the way of bringing teachers into training programs --

1. Prospective teachers:

    There are extensive requirements for teaching credentials or certification.

    Resistance by those who have prior historical claim to determining curricula, prevents new requirements.

    With little intrinsic motivation, students do not elect courses in science or mathematics.

2. In-service teachers:

    Little or no time for extensive study prevents enrollment.

    Pressure of other changes in elementary school curriculum leads to neglect of science and mathematics.

    Distaste for science and/or mathematics leads to avoidance.

    Failure to see need to change from the traditional implies no need for training.

    Distance from available courses, workshops, etc. prevents enrollment.

    If a consultant is not available in a school district there is no ready source for short range training or answers to immediate needs.

B. Obstacles to appropriate influence upon teachers who are engaged in training programs --

1. Prospective teachers:

   Courses often are taught by professors who are not aware of the attitudes and problems of those planning to teach in elementary school.

   Many prospective teachers have a history of difficulty with and distaste for science and mathematics.

   There is no readily apparent relationship between academic course work and what the student expects to do as a teacher.

2. In-service teachers:

   Habits and tradition interfere with acceptance of new ideas and approaches.

   Teachers often are frightened by the unfamiliar.

   At the end of a school day teachers are tired.

   Science and mathematics courses, workshops, etc. are sometimes imposed upon a captive audience.

With obstacles such as those above, one wonders if it is necessary to try to overcome them all. In the next decade the best answer may be to live with some of them and find solutions that do not envision reaching all teachers. Perhaps this will mean an inadequate science and mathematics program for many children. Hopefully there will be alternate methods which will reach children while bypassing some teachers.

(3) What should be the plan of attack if it is desirable to upgrade the level of instruction pupils are receiving in science and mathematics at the elementary school level?

By stipulation, it is desirable. Considering the obstacles mentioned above there must be alternative plans of attack. Long range plans should include those who are now in college as well as prospective teachers who may be no more than 11 or 12 years old at present. Short range plans should start with those who have contemporary curriculum materials available, and soon extend to make materials and training available simultaneously to others.

Specialized teachers will be part of the answer for both the near and distant future. With the advent of flexible programs of various types there will be opportunities for specialists. It is essential that mathematics-science specialists be called upon in various roles. In some cases with well prepared teachers there may be need for only a consultant, in others the specialists may teach all of the science and mathematics.

The following suggestions offer various approaches to the upgrading of instruction. Some reinforce each other, some are divergent.

A. Short range, where change is contemplated -

1. A resource teacher or consultant should be available to all teachers embracing a new science or mathematics program. Whenever a significant change is made there should be provision for one teacher in each school who will serve as a resource teacher. (A discussion of resource teachers will be found in Appendix A).

2. Demonstration of desirable teaching situations should be present to all teachers who will engage in a new program. At the least, teachers should observe a demonstration lesson, or lessons, with young children called together for that purpose. A better situation would involve visits to a class where the new program is being carried out successfully. If possible this should be supplemented with demonstration lessons by a specialists (resource teacher or consultant) in every classroom.

3. Where extensive changes are to be made it is advisable to have a preliminary summer program for teachers. This can be as short as two weeks if its aim is to have teachers become familiar with the materials and point of view of the new curriculum.

4. Within the first two or three months of a new program, there should be a meeting of all participating teachers. Early appraisal of strengths and weaknesses will go a long way toward the development of acceptance.

5. Whenever feasible, the consultant or leader for a new program should hold meetings at one of the participating schools. Where a college or university is the best central location for all teachers to meet, there should be some provision for college personnel to visit the schools.

B. Short range, where it is necessary to stimulate change -

1. Professional organizations, e.g. N.S.T.A. and N.C.T.M. and their local affiliates, should sponsor regional meetings designed to interest elementary teachers. Two or three easily instituted changes should be discussed and, if possible, demonstrated.

2. Curriculum development projects should encourage demonstration meetings for non-participating teachers. For example, a given school district which is using MINNEMAST could prepare a Saturday presentation to which they invite teachers and administrators from neighboring districts.

3. Presentations and demonstrations should be made to teachers during the normal course of their school day. One method is to present a demonstration lesson during a regularly scheduled faculty meeting. A better, though more difficult, way is to have a traveling specialists visit schools and given demonstrations.

4. Teachers should be supplied with selected worksheets and short units from contemporary programs. These should be chosen so that they are as self-contained as possible. The changes they illustrate should be evident, and should stress new approaches more than new content.

C. Long range, for in-service teachers -

All of the items in section (3) B above, can be modified to stimulate change over a longer period of time. In addition there are the following.

1. A representative group of teachers should be asked to determine a timetable for review and evaluation of the science and mathematics program. They must consider the pressures of all other curricula, but should commit themselves and their colleagues to upgrading science and mathematics during some designated year.

2. Feasible and desirable changes should be examined the year before they are to be instituted. The success of a change is directly correlated with the extent of preliminary involvement by teachers.

3. Periodic review of textbooks and other classroom materials should be acccompanied by long range goals.

4. If teachers feel that they are poorly prepared for contemporary programs, they should be given the following alternatives:

   (a) participating in a training program, specially designed for them if possible; (b) sharing responsibilities with better prepared teachers; (c) accepting a specialists teacher or departmentalization; (d) justifying the program for which they feel adequately prepared.

   The latter alternative should not be downgraded. There is much to commend a high quality traditional program, taught by a teacher who is convinced of its merits.

5. There should be widespread presentations (papers, panels, demonstrations, materials, etc.) concerning contemporary science and mathematics for elementary schools. These should be made at local, regional, and national meetings of all related educational and scientific organizations. This includes conferences of administrators, supervisors, teachers, researchers, curriculum specialists, and academics. It will require a certain agressiveness, but there is room on the program for almost any group that is not devoted to some other discipline exclusively.

D. Long range, for prospective teachers -

Provision for prospective teachers should be made immediately because every delay compounds the problem of the future. Why have new teachers leave our colleges and universities with the same deficiencies that we are trying to correct among experienced teachers? Nevertheless changes will take time, so it becomes a long range problem.

1. The quantity of course work has an influence upon the preparation of teachers. Various national professional groups have made strong recommendations for requirements for teacher training. These should help obtain a minimal amount of required courses for a degree and/or certification.

2. There is a need to improve the scope and quality of courses for prospective elementary school teachers. Most important in this regard is a multi-dimensional communication. Those responsible for the professional education of teachers must talk to and listen to the academicians in science and mathematics. Both groups (education and academic) must listen to experienced teachers - we may have already talked to them too much. Students (elementary and college) should be involved in some of these conversations; their reactions are usually very enlightening.

3. Teaching in elementary schools should be encouraged, with recruitment, among people already knowledgeable in science and mathematics. If they know that there would be a significant place for them, they might be willing to fit into the category of "prospective teacher".

4. The present day junior and senior high school curricula is an ideal place to begin the preparation of elementary school teachers. Would that some experienced teachers had the knowledge and attitude which is engendered by our better secondary school programs. To emphasize this quality we should encourage interested secondary school students to bring their newly found skills to a group of younger children.

   An important corollary to this idea would be the stimulation of socially deprived and oppressed students. There is a vast amount of money and effort now being expended to help students who are outside of the mainstream of our culture. We should try to locate those who are interested in science and mathematics and help them get the immediate gratification of helping others. We may find a rich source of prospective teachers who will be highly qualified in six to ten years.

5. Prospective teachers may be recruited among the adult population and given adequate preparation in science and mathematics because they seek it. For example, hiring program of teacher aides and other paraprofessionals should include some people with special responsibilities in the laboratory aspects of these subjects. Among that group there should be many who could be encouraged to become fully certified teachers.

E. Other long range considerations -

For many years to come, we can expect a shortage of teachers who are well qualified in science and mathematics. For the unqualified, and underqualified we should develop materials which they can give to children with a minimal of supervision. Some may be nothing more than supplementary units for isolated use. All should display the flavor and attitude of contemporary curricula.

One will note that the answer to this question has been focused upon the preparation of teachers. It is in the details of this preparation that consideration should be given to curriculum, learning theory, development of attitudes, etc. In other words, I have consciously restricted discussion to the structure of teacher preparation rather than its content.

(4) Are there now in existence college and university personnel who could provide regional leadership in developing projects to improve the elementary school science and mathematics offerings? How can they be identified?

At this stage in educational history there seems to be adequate leadership for big ideas and major projects. We are faced with an inadequate supply of qualified professors to do all of the required work to develop and disseminate these ideas.

I would recommend that a concerted effort be made to involve junior members of college faculty. In particular someone with the appropriate specialty may be given the task of consulting with colleagues, both those active in science/math, education and those who are removed from it. His consultation should be oriented to a given regional need, and will thereby be a medium of information as well as one of inquiry.

At the other end of the spectrum are senior members of the faculty who have never been asked to work with teachers. One of them might very well be requested to seek a solution through consultation with colleagues and school personnel. The leadership for this type of regional activity may very well come from the academic, or research oriented, professors. An examination of staff on major curriculum projects will show that this is no idle comment; if it can be done nationally it might well be done locally.

To locate the junior faculty, one can ask graduate schools. Then it is necessary for someone to follow-up with inquiries and suggestions to new appointees and their department heads. It is more difficult to identify likely prospects among more experienced professors. Perhaps the approach is to let them know that they are needed, and let them identify themselves. Professional societies and state departments of education might well cooperate in such a broadcast appeal. In any event, potential leadership should not be lost because it was not requested.

> (5) Is there a need for a national office or center to coordinate operations to attack the problem -- does one exist now without clear identification?

"In any event potential leadership should not be lost because it was not requested." This statement, concerning item (4), points up the value of having some central person or office to at least inform others that their efforts are needed for teacher education in science and mathematics.

Just as there are ambitious projects to accumulate and disseminate information about research and curriculum, there should be one related to teacher education. I see its role as something more than a repository of information, but something less than a coordinating agency. It should be almost a public relations organization which would let all appropriate professors know of the activities and problems related to upgrading elementary school teaching of science and mathematics.

> (6) What are the necessary ingredients of a successful teacher education program which introduces the new science and mathematics curriculum at the pupil level?

Necessary? A teacher should a) be prepared well enough to read and understand the pupil materials and accompanying teacher manuals of the new curriculum, and b) become attuned to contemporary approaches so that he does not stand in the way of proper student use of materials. These two necessary characteristics of a teacher point to the necessary ingredients of a teacher education program which accompanies new curriculum.

A discussion of pertinent details is found above, section (3) A - a short range plan of attack where change is contemplated.

> (7) Can the second or third generation teacher in a pyramid approach (teacher teaching peers) act as an effective agent for program adoption? Consider teachers cross-trained in mathematics and science.

As one gets further from the source there is certainly a diminishing impact. Changing the analogy to that of a pebble at outlying ripples. You can't make big waves with one little shot.

The most hopeful aspects of the pyramid approach include the following:

A. Each resource teacher becomes stronger with each peer teaching experience. For example, if he was stronger in mathematics than in science, his peer teaching would present him with both the need and opportunity to balance his knowledge.

B. The original resource teacher is often encouraged to become a key person in his school or school district. Many such teachers have been known to extend their own education so they are now well qualified specialists.

C. At each generation there is a similar stimulation for the central teacher to become more involved.

D. The resource teacher, at any generation, can effect some positive change if he attempts to accomplish no more than he can do in a stimulating manner. For example, a health change in attitude will often result from the observation of a well taught lesson by a "non-expert" peer.

(8) What role can the Elementary-Secondary Education Act with its various titles, The Education Professions Act and The Higher Education Act play in seeking a solution to the problem of support for teacher education or leadership development?

(9) What types of consortiums of colleges, universities and school systems may be necessary in attacking the problem of teacher education or retraining?

These two questions are linked because the various sources of federal support can and should encourage cooperative action. It is not just that there will be money available, but that these funds should help bring educators together from various organizations.

It would have a salutory effect if a consortium were to have its focus at a school where the students and teachers are using a new program. It is easier to bring knowledge and supplies to the users, than it is to bring school experience to the expert. In other words, the interaction of students, teachers and consultants should include an emphasis on the final result.

A model for a consortium would include the following:

A. Representatives from public schools, including both teachers and administrators.

B. Representatives from School of Education

C. Representatives from academic departments of college.

D. Representatives from an independent educational organization, e.g. a regional educational laboratory, or a curriculum development group.

The several responsibilities of each group will vary from project to project, but none should be neglected. In particular each should be encouraged to take a somewhat broader view of his position than is usually the case. For example, the public school persons and academic representatives may each think of doing more teacher education. On the other hand the education professor may move toward the substantive aspects of science or mathematics. A consortium should be a truly harmonious association.

(10) What types of organization structures are most economical in affected classroom level change in the teaching change in the teaching of science and mathematics in the elementary school?

For the most part the answer to this question is discussed above in section (3), the plan of attack. Any type of organization for change requires two ingredients: a) contemporary materials suitable for pupils and b) someone to help the teachers use these materials. The more easily available these are, the better they will be used.

(11) What are the necessary relationships that should be found to exist between science and mathematics at the elementary school level? (Reference here is the Cambridge Conference of September, 1967)

This question would diverge from the stream of thought which has been emphasizing how to accomplish change. It is perhaps best left to another position paper, or the references to reports of other conferences and curriculum projects.

(12) How must programs be different in schools for the inner city population and the southern and western schools, particularly those with a heavy concentration of Negro, Spanish-American and Indian, where language and cultural differences are important factors?

Science and mathematics programs have the distinct advantage of being able (easily) to use non-verbal approaches to teaching and learning. Whereas laboratory experiences are recommended in any school, they become essential for the situations described above. To a very large extent the classroom will be the only environment from which culturally different children can derive experience related to science and mathematics.

What should this environment include? Primarily it must be one to which the children will want to relate for its own sake. It must appeal to their present interests or stimulate interest where none now exists. Wherever possible there should be an abudance of manipulative materials. These will serve to give direct experience without the intermediate interference of unfamiliar language. Furthermore, these materials often are introductions to features of our technological society, e.g., thermometers and scales.

In a similar way the science-mathematics program should be an introduction to the society external to students' limited experience. Field trips can serve this function, and those with an emphasis upon investigation are rather simple extensions of contemporary programs. Consequently, any teacher education program should include information about how such extensions might be made.

There is some special advantage claimed for science and mathematics program in the education of these special students. It is said that all students start with the same paucity of scientific knowledge, so no student need feel disadvantaged. To the extent that this is true it should be stressed. For example, a study of astronomy or number theory can provide every student with all of the resource information needed. In general, teachers should be made aware of the fact that they often assume that children have certain background information from home and society. Then, they will be more ready to select activities and topics for which they can provide all necessary resources.

On the other hand, there is sometimes a special core of cultural knowledge or interest which should be recognized. For Indian children this may be extensive information about natural phenomena, for city kids it may be a curiosity about construction.

Finally, programs for inner city schools, etc. should be better than others because there is now a lot of money being spent for them.

This is an appropriate comment on which to end. There is money available; there are qualified people available -- let's have them ask for each other.

Resource Teacher for Science and Mathematics in Elementary School

The following is a list of activities which might be conducted by a resource teacher.

- Intensive Workshops
- Enrichment Lectures
- Materials File
- Cooperative Study
- In-Service Courses at Local Colleges
- School Professional Library
- Textbook Study
- Research Group
- Experimental Program
- Television Teaching
- Test Construction (school wide)
- Field Trips for Teachers
- Local Conferences
- Demonstration Classes
- Interdistrict Cooperation
- Articulation Committee
- Cooperative Planning
- Parent Education Course
- New Teacher Conferences
- Teacher Discussion Meetings
- Participation on Curriculum Study Committees
- Material Workshop
- Informal Seminar Groups
- Micro Teaching
- Film Festival - films for teachers and/or students
- "Briefing" of teachers for student problem contests

"Effective Models for Training Teachers - A Response"*

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It is not my purpose at this time to defend the position taken in the proposal which brings us together nor to respond to statements made in the other two position papers--except as the bear upon teacher training models. I am pleased that the position papers did tend to focus upon the questions offered in the proposal which I considered most important.

Professor Feldman went to some length to point out some obstacles to bringing teachers into training programs. Although to some persons this may seem diversionary action to avoid the issue, I must support his approach since it is necessary to know the odds before launching an attack if best use is to be made of the resources at hand. Having thus taken this position with Professor Feldman, I would like to add two or three dimensions not specifically pointed out but which may be present by implications. Having added these I now want to turn my attention to another area of personal concern--which I have expressed in the small sessions.

The paper presents what is the crux of the problem of teacher training in a brief but powerful statement which I will quote here. "Modern programs include more than a set of new information; they try to convey new attitudes about learning and understanding." When exploring this statement in the light of past educational goals it appears that a different philosophical thesis is being proposed by new programs. Although it is generally recognized that education should be divergent in its effect upon persons, making them different; essentially all research tends to support the conclusion that our nation's school systems tend to produce sameness among persons who have "successfully" passed through these systems. You will note the avoidance of the term "individuals" since in my experience and my review of research there seems to be little to support the contention that there is opportunity in our educational system for individuality. The major exception is in the lip-service paid to it in essentially every seminar, school faculty meeting, and inservice training program. Teachers are not allowed to make use of individuality in their teaching methods and do not allow for it in their classrooms. Closure, directness and absolute values are emphasized. Can an educational system so strongly steeped in a teaching approach which rewards rote memory, precise answers to unclear questions and the ability to "psych out the teacher" in order to "know what answer the teacher wants"--accept new programs based upon "new attitudes about _learning_ _and_ _understanding_?" The answer, in concurrence with Professor Feldman is no! At least not on any broad scale over any reasonably short time schedule, since limited funds, personnel commitments, "the establishment" and all the other things inumerated by Feldman, stand in the way.

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* A response to the position paper by Dr. Leonard Feldman. Belmont Conference, Belmont Estate, June 26-29, 1968.

I am not certain what Professor Feldman meant by "new attitudes and learning and understanding". I have a "gut" feeling for what I think he means perhaps you do too. Nevertheless, at this point let us assume that we all agree upon what is meant by, and concur with, a list of "attitudes about learning and understandings" as might be compiled by Professor Feldman. What would this list tell those of us interested in training teachers? Would it be of assistance if the list were reduced to behavioral goals? Recall that such goals are terminal behavior observations and say nothing about how they are reached or indeed what teacher behavior patterns or "teaching" which might cause them to be developed. It might not, incidently, be too far afield to suggest that such desirable terminal behavior could be brought about by a wide variety of experiences or complex behavior patterns. Likewise, the observation of the desired terminal behavior may or may not mean it would be consistently repeated in later incidents! My concern is that we accept the behavioral goals as a means, not an end itself. Davis also discusses this point in his position paper.

Where, in terms of elementary school teachers, are attitudes about learning and understanding developed? Some of them are introduced and reinforced in our lower schools and are carried to the university to be strongly reinforced over and over again. Approximately 21 times each four and one-half months, based upon 128 college semester hours for graduation, a 3 semester hour module for course work and four examinations per course; the student rewards are passed out. Each reinforces an attitude which I am embarrassed to say, is the antithesis of what Professor Feldman, and most of us would like to have developed. Hence for those of us involved in teacher preparation programs our job begins in our own institutions in our undergraduate courses taught by our colleagues. Perhaps no teacher is more difficult to change that the college professor--he knows what he knows and how it was presented to him in his attendance at lectures and professional meeting. Hence, he will present it in a similar manner to his students. The emphasis frequently is upon precision, closure, and directness in presentation of material. Why waste time--just tell them!

All is not as dark as it may sound however. There have been conducted by educators at our institution, two studies for which I have the greatest respect. The reason being, that they hold out such high hope for education of prospective teachers for all levels although the studies involved only the program for secondary teachers. Both studies were conducted by Dr. J. T. Sandefur Professor of Education, Kansas State Teachers College and Associate Dean of Academic Affairs. The first, funded by U. S. Office of Education[1] involved the acceptance of the premise that what was being done in professional education courses was basically wrong. The typical undergraduate curriculum for secondary teacher education at Kansas State Teachers College is a basic liberal arts degree plan with (20) twenty semester hours of psychology and professional education substitued for major field courses in the senior year. This is somewhat over simplification but that is essentially the pattern. Substituted for the junior-senior year in the experimental sequence was a program which had the following ingredients: (1) emphasis upon prospective teacher's early involvement with secondary students and experienced teachers in a learning situation, both live and on video tape; (2) all professional education courses were taught in an indirect manner with reference to Flander's definition; (3) all professional education courses were established upon the foundations of education approach (psychology, sociology, anthropology, and philosophy); (4) prospective teachers were taught and subsequently used interaction analysis to evaluate teaching sequences both live and on video tape including tape sequences of themselves and their peers; (5) prospective teachers met in small groups and discussed their teaching experiences, teaching which they observed, and behavior of secondary school students and teachers. Constant reference during these discussions was made to the foundations mentioned above and the major works which were used as reading references in these foundations.

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[1] Sandefur, J. T. and others, "An Experimental Study of Professional Education for Secondary Teachers". Cooperative Research Project 2897, U. S. Office of Education, July, 1967.

The results of this study showed some remarkable differences in behavior between the experimental and control groups. (1) Students in the experimental program were consistently selected by the project evaluators, supervising teachers, students and school administrators as being superior classroom teachers. (2) There was a significant difference between the teaching behavior of prospective teachers enrolled in the control program and those enrolled in the experimental program as measured by independent observers using the Classroom Observation Record.[2] The experimental group received the more desirable ratings. (3) There was a significant difference in the behavior of the school *pupils* of the experimental and control teachers as measured by independent observers using a sixteen category system of inter-action analysis. The experimental group was found to use significantly more indirect activity. (5) Grades earned in student teaching were significantly higher for the experimental students than were those of the control students. Significantly higher scores were made on the Professional Education section of the National Teachers Examination by the *control students* than were made by the *experimental students*.

A follow-up study after one year of experience has been made, but has not yet been published. This study indicates that instead of regression the experimental group has increased the gaps that initially existed between them and the control group. In fact, after one year of experience the control group still failed to measure up to the experimental group's pre-experience mean scores in areas where significant difference initially existed. A most interesting and important finding, I believe. Needless to say, our institution is adopting the essential ingredients of the experimental program as rapidly as space, faculty, facilities and money permits. My point here is this. Over the period of no more than two years we were able to produce teachers whose attitudes were favorable toward indirectness and who displayed more of the desired characteristics of a teacher *as defined by persons outside of our institution*, than were displayed by teachers with one year of experience who followed the program normally used in most teacher training situations. There has been no big splash as a result of these studies. This is mainly because the research takes on "the whole establishment" and has not well defined what components seem to be the effective agents, an exceedingly bad thing to do from experimental design view point. Yet the *process* can be defined totally, by a pragmatic examination, and the results are so significantly different from those obtained by the conventional program that I personally questioned the data, statistical design and computer programming. I subsequently found them above reproach.

Here then are some hard data to support the contention that beginning teachers need not have all the old attitudes about learning and understanding. Yet, some of the same barriers, which Professor Feldman mentioned, presently exist at Kansas State Teachers College and deny complete adoption of the program for all prospective teachers which are leaving our school.

Turning our attention to the suggestions Feldman offered for "upgrading of instruction" through inservice education of teachers there are several things that should be stated. First, let me say he has some excellent points and it is my sincere hope that those who are in a position to implement the suggestions or publicize them will do so. I am particularly referring to the role of professional organizations that might stimulate change by conferences and meetings using a variety of ideas to capture the imagination of educators at all levels. Action is needed to bring about "attitude reform" among our teachers. Similarly, we must be active individually and as a profession to educate the public to this need. Curriculum improvements through adoption of modern mathematics and science programs, coupled with teacher training or re-training has centered about individuals who are energetic and capable. It is absent elsewhere. The importance of individual initiative can only be superceded by public awareness and demand!

I concur that schools instituting curriculum changes involving new programs in science and mathematics should give attention to the suggestions offered by Feldman. However, it is only fair to point out that substantial funding is needed to provide the number of curriculum specialists, resource teachers, consultants and demonstration teachers required by him. This point is briefly discussed by Davis and must be of major concern to all of us. Although the national goal has been equal educational opportunity for all, it still appears, even with government funding, that when we speak of 1.5×10^6 teachers who need training of necessity we may be forced to say "excellence where it is possible now, elsewhere when funds are available". It is a tough decision then, to decide who and where first.

Part of the answer to the questions just posed may be found by raising another question. That is, "which systems have the personnel available in adequate quantities to carry out the task?" There are not now identified in Kansas, enough curriculum specialists, resource teachers, consultants and demonstration teachers, with adequate training, to supply the demand that exists. As Feldman indicates some program, perhaps locally orientated, needs to be instituted. The University of Texas Science Teaching Center has been an outstanding example of what I mean. Admittedly, the persons active in that State are nearly all, recent graduates of Texas U. but the job they are doing could well be emulated elsewhere. Some other programs with variations are found in other places across the nation, they need publicity and support!

Another item which Feldman points up indirectly but does not expand upon has to do with program evaluation. He alludes to the necessity for a meeting of teachers in the first two or three months of operation of a new program. This I strongly support. However, attention should be given to evaluation of the program and of pupil progress at this time, too! This evaluation is crucial, since teachers frequently must justify widely divergent indicators of success by pupils who have previously not been in a new program and may still be memorizing their way to failure or who may suddenly blossom. Parents do not understand, pupils may not be able to explain it, principals and superintendents may not want to hear about it, hence teachers must be able to "carry-the-ball" on this public relations task. Certainly "new attitudes about learning" will result in an evaluation of a different type.

In referring to long range programs for upgrading instruction, Feldman heads his list with the desirability of teachers establishing a timetable for review and evaluation of programs. This can be supported if the review conducted is properly centered. All too frequently this is done by bringing in the soft ware and textbook and/or equipment salesman. Evaluation is thus too frequently based upon the finesse and abilities of the salesman, appearance of text, colorful materials and packaging; not upon utility, and usefulness in teaching children. There are no apologies being offered to my friends in the commercial field, that is how they make their money and we both know it.

When considering involvement of teachers in curriculum change is discussed by Feldman, he fails to bring out the importance or perhaps the impotence of "gradual change". There is something to be said for a slow change in terms of committment of the system to a sizeable outlay of funds. However, it is my opinion that a "gradual change" frequently means, from the viewpoint of teacher and administrator, no change. At least it means the change takes place only in-so-far-as the materials, equipment, text, and vocabulary can be adapted to the structure of courses (or curriculum) as they existed for the teacher initially. A prime example of this, I contend, is found in the textbooks of mathematics -- they run the spectrum in terms of degree to which they offer a modern approach to mathematics. In my estimation, the result is great internal inconsistency in "attitudes about learning and understanding". The pupil is confused and the teacher cannot adopt both philosophies. The curriculum resulting frequently becomes ineffective in reaching desired goals. Incidently, a clear explanation of this phenomena would be appreciated if I speak out of turn. As indicated in another paper, by putting in a few Venn diagrams and changing the words in texts, you do not have another math program!

What has been said about gradual change is particularly applicable to certain elementary science materials. The AAAS materials do not appear to me to be subject to partial adoption in any one classroom. Grade-wise, yes, partially within a grade, with other programs on a pick and choose basis, no. Again, please correct me if I err. On the other hand, the ESS materials which I have examined, could be used as a supplement curriculum particularly if no science is being used at all. However, the attitudinal difference between the conventional read-about-and-show approach and the ESS approach are by their nature incompatible. This does not mean to say that anyone should offer a program as a panacea. Curriculum or program modification has been and will continue to be necessary, yet it is my hope that radical change in "attitudes concerning learning and understanding" would not be as great in future program modification once a system moves away from the didatic teaching methods all frequently found at present.

Considering prospective teachers again, Feldman refers to long-range considerations. It is true that many states do not have requirements in math and science for certification. But what I consider just as bad, is the use of trigonometry, business arithmetic or Calculus I to meet such requirements in mathematics or six hours of credit in "Lectures in Engineering Physics" to meet all the requirements in science. Not only should courses be required, but the content needs attention! Reference was made to this point in our group discussion yesterday when Ed Kurtz referred to the study made during evaluation of AAAS materials. Science courses for prospective elementary school teachers ought to have the following important aspects, among others:

1. employ a "hands-on" type laboratory experience of at least one-hour duration per week for one year (9 months).
2. develop the concepts of inexactness of observation and the tenability of conclusions.
3. establish that much of man's knowledge comes from observation of phenomena and experiments which can be replicated.
4. exploration of the relationship between man's limited observational capacities and his instrumentation.
5. show why man believes what he does about change, atoms, molecules, life, charge, inter-dependence between plants and animals, and other topics which have broad application and explore interfaces between what we normally call academic disciplines.
6. the course(s) should be taught in a manner consistent with the philosophy of modern science curricula for the elementary school. (Note: this does not mean an elementary school science methods course!)
7. emphasis should be upon how information (facts) can be used not how much can be recalled!
8. instructors should be aware of the basic fear and anxiety about achievement in science, which most females have, and should constantly and openly express sincere belief that such fear and anxiety can be overcome.

There are many other things which could be enumerated but the point is that the course as taught, is just as important as the requirement of such a course for certification. We ought not to expect elementary school teachers to behave any differently than we do when teaching science! After all what other model do they have? Teacher preparation institutions should take appropriate steps.

Still considering long range programs for prospective teachers, let me say that one of the most delightful experiences on our campus this past year, in terms of an informal program in teacher education, involved college freshman and sophomore girls becoming acquainted with ESS materials in an informal non-class setting. They were fascinated by the approach to learning, they taught each other, and were anxious to learn more about how children would react to the approach if they (college students) tried it on elementary pupils. The ease with which these college students adjusted to the use of the materials and the indirect approach was very satisfying. It further supports our suspicion that although poor attitudes toward science can be well established among prospective elementary teachers the attitude can be changed using appropriate techniques of instruction, namely those consistent with the behavior patterns we expect to be displayed by the elementary teacher as she teaches science.

Feldman, in referring to recruitment programs, calls attention to the adult population as a source of teacher aides, paraprofessionals and teachers. It is well to remember here, that perhaps persons who, (a) have no preconceived idea about math and science teaching in the classroom and, (b) have the sensitivity to work with youth of an early age, may provide an excellent potential source of personnel. However, recall that what we are dealing with is a somewhat subtle thing, an attitude about learning, and those without classroom experience may not be easily molded into the resource person anticipated. Regardless, such sources should be explored as should the other personnel sources listed in the Feldman paper.

A long range consideration mentioned by Feldman, which I consider particularly meritorous, is the concept of "supplementary units for isolated use". This type of unit if properly handled in the classroom could be extremely useful. The first of these that comes to mind is the ESS unit called "A-Blocks" or "The Attribute Games". The "games" provided in this unit are particularly flexible and deal with the interface of mathematics and science very nicely. An informed but overburdened teacher could utilize them in an extremely effective fashion. Teacher aides or paraprofessionals could add strength, if trained to do so, since the materials are largely pupil activity oriented.

The latter consideration leads to another observation about Professor Feldman's paper. He states twice, and infers in other places, that depth of knowledge in the subject matter is not a requisite to successful use of modern curricular materials. That a mathematician should make this observation pleases me greatly since it is the same observation that some of our staff have made about some of the science materials. Two things immediately spring into mind as a result of this observation. First, the materials must be well done in order that the uninitiated can effectively use them to show the spirit of the subject and inquiry method. Secondly, a stronger case can now be made for certain types of emphasis in teacher training. More emphasis should be put upon developing the proper frame of reference for using materials of any type, and less emphasis placed upon the manipulation of equipment. Leave the latter to the students! I personally like the statement made by Feldman that the teacher "becomes attuned to contemporary approaches, so that he does not stand in the way of proper student use of materials". The problem verbalized to me by many teachers who are doing this for the first time is "but I do not feel like I am teaching if I am not talking!" Teachers who are "attuned to contemporary approaches" quickly catch on when it is gently suggested that evaluation of pupil behavior cannot really take place when the teacher is talking and the pupil listening. It may be well for project directors, teacher educators, curriculum supervisors and others in a position where they can provide assistance to teachers; to spend some time emphasizing diagnosis of behavior as a prime requisite to good teaching. Teachers who talk too much are a distinct hazard in a laboratory setting. Questions from teachers are fine, too many teacher answers may be bad!

Professor Feldman has been extremely kind with reference to the model included in the proposal. He has not attacked the establishing of a national level office or deputy position to "look after" science and mathematics in schools. Furthermore, he has chosen to avoid an attack, which may be justified concerning the red tape of bureauacy which could come by establishing a federal, state and local office for promotion of science and mathematics education. It is extremely difficult to avoid the inefficiency of large governmental bureaus, this is admitted. However, it seems to me that unless more vigorous leadership is provided some stable communication link should be established. The National Science Foundation has provided some assistance, funding this conference is not the only move. Perhaps The Foundation is the proper national level figure to be identified, if so then as scientists our responsibility is to inform The Foundation of needs and priorities then support it in its plea before Congress.

It is hoped that no one wants a national curriculum in the United States. It is not conceivable that such a diverse nation could adopt so limited a program. Yet, in a sense it has! The nation's schools are, in the main, supporting a national curriculum based upon the false premise that knowledge of a collection of facts which can be recalled at will, is the only requisite to a successful educational experience. Our chore is to bring about reform with regard to this point of view. Attention first to the curriculum; this has been or is being accomplished. Teacher training and implementation second; this seems to be the major hurdle and is our task. Public awareness must come and favorable opinion is necessary. Because of some faltering steps in other programs in mathematics and science the ripe time may be slipping away. Already, school patrons and businessmen report severe educational defects among youth who have been in "modern math programs". "They can't even make change!", so the charge goes. Such criticisms must be overcome lest public sentiment use it as a bulwark from which to take pot-shots as any "new fangled program" that "costs too much". I offer this caution because in the long run the public must accept and pay for curricular changes. Not only that, but from where I sit I see the need for public schools, with the patron consent, becoming more deeply involved in the training of pre-service teachers. Support for such an effort on the part of the schools must not be over-looked. With the need for larger numbers of trained teachers increasing each year and with no increase in the number of laboratory schools in which prospective teachers can obtain pre-service teaching experiences, there will be a growing demand for a closer tie between the schools and colleges in developing the number and quality of classroom teacher desired.

APPENDIX B

Recommendations of Belmont Conference

RECOMMENDATIONS

BELMONT CONFERENCE

The recommendations which follow were formulated and discussed at the Belmont Conference and in essence, endorsed by all parties in attendance. The substance of the recommendations and the accompanying rationale were composed by the members of the Conference. Some editing of the recommendations was necessary to fit them into the format of this report.

The recommendations have been categorized as Research and Development, Curriculum Change (both pupil and teacher), Institutional Change and Communications, according to the type of activity or effect being sought.

Rationale and guidelines for implementing the resolutions are not provided in every instance. In some cases it was felt unnecessary and in others more study would be required before specific action could be proposed.

I. RESEARCH AND DEVELOPMENT

A. It is recommended that the scientific community, the United States Office of Education and the National Science Foundation be informed of the pressing need for financial support to establish regional, cooperative educational support systems, disassociated from the existing educational establishment wherein new, imaginative, and relevant educational programs in mathematics-science education and other subject matter areas can be fully researched and instituted into our school systems.

RATIONALE

1. There is considerable evidence to suggest that the physical and administrative structure of the American public school system inhibits, if, indeed, it does not inadvertently prohibit the adoption of contemporary science and mathematics curricular materials and/or the implementation of innovative modes and contemporary strategies of teaching. The structure forces the grouping of students by ages, imposes lock step rigidity in space planning, keeps the classroom teacher-centered, and trains students to be passive participants.

2. Administration regulations impose further rigidities on seated students in "quiet" classrooms where they are kept immobile. These regulations force inflexible teacher-centered rooms, and discourage pedagogical innovation.

3. Contemporary learning theory and instructional theory suggest that "inquiry learning" is the appropriate mode in science and mathematics at all levels.

4. The teacher who uses the contemporary science and math materials based upon the inquiry mode requires physical structures and administrative support that allows maximum flexibility, and mobility, for acceptance by students.

5. It is essentially impossible to develop real experimental programs in the existing school systems, hence new approaches to an experimental school system must be tried.

6. The inner city child has by and large rejected the present educational system; therefore, the inner city is an area which needs introduction of an experimental educational system to improve circumstances in impoverished areas; such as New York, Los Angeles, Cleveland, or Detroit.

7. Classroom Learning Centers, as experimental systems in schools, could be designed and established quickly by a group of specialists working together.

8. The Office of Economic Opportunity and city funds might be used for initial support.

9. The school district in which such an experimental system is to be developed would need to give its endorsement and should be willing to recognize and accept student earned credit, upon recommendation by the staff in the experimental system.

10. The learning center population would include all ages, including adults. The traditional patterns of grades, physical separation, and restrictive class scheduling and grouping would be abandoned. All new technology would be used, and mathematic-science subjects would be integrated where possible and appropriate.

B. It is recommended that leaders of curriculum projects, publishers of textbooks and instructional materials be asked to specify minimal behavioral objectives and provide supporting analysis and rationale. In addition, evaluation data on attainment of these goals by the learner under specified field conditions should be provided. It is further recommended that this evaluation information be disseminated widely.

RATIONALE

Such information is needed to enable school systems, teachers, science coordinators, and other decision makers to compare answers to these questions:

1. Are the goals for the materials similar to the goals we desire?

2. What kinds of schools, teachers and students have used the materials?

3. Which of these schools, teachers and students have been successful or unsuccessful with the materials. How was success measured?

4. Are the measuring instruments reliable, valid and accessible?

5. What teacher education materials are available and is there evidence that they enable the teachers to be more successful with students?

C. It is recommended that scientists, mathematicians, behavioral scientists, classroom teachers, and specialists in research design, cooperate with school systems to perform in depth case studies and longitudinal studies of the effectiveness of contemporary elementary science-mathematics programs in bringing about desired changes in students and teachers within the existing physical and administrative structure of American school.

RATIONALE

1. More basic research must be done to determine the impact of new science-math curricular material on students and teachers.

2. Each school system should define the desired goals it has set for its students in study of particular science-math materials. Evaluation should measure their attainment and the impact of the program on the student.

3. Some kinds of questions which need answers are:

   a. Do the experiences that students have with AAAS materials actually cause the students to acquire a behavior that he transfers and applies to other appropriate situations?

   b. Are the student behavior patterns acquired in grade 3 changed appreciably or strengthened in grade 4, 5, 6, 10, 12?

   c. Do the ESS units exert equal influence on students with convergent and divergent habits of thought?

   d. What concepts of science do the sixth grade student demonstrate that he understands?

D. It is recommended that the behavioral characteristics of a teacher who acceptably teaches a specific science or mathematics program be described and illustrated on film or video tape for pre-service training of tomorrow's teachers.

RATIONALE

1. School systems need such descriptions so that they can identify teachers who already are demonstrating these characteristics and provide for merit recognition.

2. Persons conducting in-service or pre-service teacher training programs need them as illustrative examples.

3. Teachers need them to reinforce their actions and evaluate their own teaching.

4. By identifying these characteristics it will strengthen the program by identifying the teacher element necessary for success of the program.

E. It is recommended that systems of individualized instructional materials for teacher education in science and mathematics be produced.

RATIONALE

1. The number of elementary teachers required will continue to increase.

2. The science and math curricular materials will continue to change.

3. Elementary teachers will need continual in-service guidelines for use of new materials and teaching methods.

4. It will become increasingly difficult to bring teachers together in institutes at night, on weekends, or during the summer.

5. It would be desirable to prepare teacher guideline packages for the use of science-math materials by use of audio tutorial, video tape, film, and computer assisted units.

6. If these technologies are properly used, the teacher could have in the classroom, and/or in a learning center in the school building, self-teaching teacher preparation resources that would be immediately available as needed.

7. For example, a teacher using the AAAS materials could have available in her classroom video tapes of exemplary teacher and student behaviors for all student exercises.

8. Enrichment notes or background information on topics, with which teachers have difficulty could be provided on audio tutorial programs.

9. Teachers and students could communicate via terminals with a computer center at a College, University or Consortium center to obtain information, to feed in programs, or to receive assistance in solving problems of the classroom.

10. Video tapes, loop films, in audio tutorial programs could be used in simulated discussions, evaluation or in many other ways.

GUIDELINES FOR ACTION ON THIS RECOMMENDATION

These materials must be available for use in a central facility of a school system. Teachers would begin at their own level of competence and proceed at their own rate. Video tapes, equipment, guides, self-appraisal times, and other self-instructional materials would be required. Staff members should be present to provide assistance when needed. Both content and instructional strategies should be included and considered in the objectives for development of these materials. The materials available should be suitable for several curricula and varied needs of teachers. In some cases materials could be checked out for use at home or in the classroom. By means of this teacher education system, many teachers could be helped with a minimum number of supporting personnel.

F. It is recommended that funded curriculum development programs relevant to math-science be instituted for the undergraduate training of elementary teachers. It is further recommended that this program be developed for use by college instructors.

GUIDELINES FOR ACTION ON THIS RECOMMENDATION

1. Institutes could be established to thoroughly acquaint college instructors with this program.

2. It is envisioned that the institute participants will return to their colleges and organize a course of 6-8 semester hours.

3. This course will deal with a variety of approaches to the teaching of science and mathematics in the elementary school.

4. Whenever appropriate, the interrelationship between math and science will be emphasized.

5. The course will be centered around three major types of activities:

    a. Discussion of the philosophies of goals of the various modern approaches to the teaching of math and science.

    b. Involvement in representative classroom and laboratory activities.

    c. Observation of, and participation in, actual elementary classroom activities.

6. This program should include such components as text materials, audio visual aids, representative classroom and laboratory activities, micro-teaching exercises, and video recordings which will explain, support and demonstrate the philosophies, the purposes and the concepts underlying the more modern approaches to elementary mathematics and science.

II. INSTITUTIONAL MODIFICATION

A. It is recommended that the teaching of science and mathematics in elementary schools be integrated wherever possible and appropriate.

RATIONALE

1. We encourage the continous experimentation, adaptation, extension and even modification of present major math-science curriculum project materials as efforts to improve understanding and success in teaching these new programs. We believe that more personnel associated with these national projects should be specifically trained and made available to assist school systems in such experimentation across the country.

2. Dade County, Florida has proposed to implement the Cambridge conference guidelines with an action program that will provide for math-science laboratory teachers and coordinating teachers trained in both areas. Such action is to be commended and provides a model for other systems to explore and emulate insofar as possible.

3. More direct individualized pupil involvement is needed in mathematics-science curricula to attain contemporary behavioral objectives in the classroom.

GUIDELINES FOR ACTION ON THIS RECOMMENDATION

1. Develop courses which unite the methodology and content of both mathematics and science.

2. Develop courses integrating the conceptual content of science and mathematics where possible and appropriate.

3. Provide prospective teachers with opportunities for contact with elementary school age children informally or in formal classroom situations prior to the beginning of their professional education pre-service program.

4. Involve prospective elementary teachers in experimentation and development of new curricular activities.

5. Provide for the development of an "area-concentration" (i.e., math-science, social studies, communication skills, and creative arts) as part of the teacher's pre-service program.

B. It recommended that special programs be established which will train selected consultants, coordinators, teacher training personnel, and resource teachers for the newer programs in elementary science and mathematics.

RATIONALE

1. Competent teachers play a strategic role in providing a learning climate where children gain insights into scientific and mathematical concepts and begin to develop personalized modes of inquiry.

2. To expedite more successful implementation of the new programs, a larger number of qualified instructors is needed to conduct training sessions for classroom teachers.

GUIDELINES FOR ACTION ON THIS RECOMMENDATION

1. Participants should be selected on the basis of interest, proven competency, on a commitment to the program.

2. The length of the training programs should be commensurate with the objectives of the program and the needs of the individual participant. A program may continue for a six week period during the summer or during the academic year followed by a series of evaluation sessions.

3. To insure success of the training session, consideration should be given to released time, college credits, and/or financial aid for participants. Additionally, school administrators of participating districts, should be expected to make commitments with regard to the successful implementation of the program or programs into the classroom.

4. Funding of such a program could be established through the National Science Foundation, the United States Office of Education or both.

C. We recommend that: (short term)

A thorough analysis be made of pre-service teacher training programs to help prepare teachers for improved understanding and efficient use of computers and calculators.

a. New and improved instructional programs and materials should be developed to meet needs in this area.

b. Materials should be developed to assist elementary school students in understanding use of simple computers and to understand their expanding role in our society.

RATIONALE

This recommendation is borne or the belief that citizens in a free society must be as informed as possible about their society. America today is dependent on technology; some speak of our "technological society."

Electronic computers, data processors, and other calculators are becoming an increasingly important part of this technology. We encounter them, or their influence in almost all of our daily activities. These technological devices are presently being used to assist in instruction. Their use in this area will certainly increase. It is imperative that teachers become familiar with them and understand their limits and potential as teaching aids. Their training should include preparation for operating the machines themselves.

The earlier in life one becomes familiar with mechanical and electronic devices, the earlier one is able to understand the devices and absorb them into personal experience and habit. Elementary school students should begin to learn some of the fundamental principles that pertain to the use of computers and calculators. Contemporary telephone dial systems are an example to be understood and appreciated. Moreover, these pupils can learn some mathematical and scientific concepts and skills by actual use of calculating devices.

Finally, such machines have already become sources of employment and opportunity even for persons who do not possess advanced academic training. Understanding and facility in the use of computers and calculators will be a necessity for career opportunities for many youth tomorrow.

D. It is recommended that, immediate efforts be made to combine and unify a "methods" course, a "contents" course, and practical experience in teaching and observing children in elementary school mathematics; this to produce a single integrated experience for college undergraduates who expect to become elementary school teachers. (A similar arrangement could be developed dealing with science and at a later stage, to relate the mathematics package to the science package.)

RATIONALE

1. Teacher training programs must prepare teachers for the new professional expectations placed upon them and help them understand how to avoid obsolescence.
2. Undergraduate curriculum development or redesign has not kept pace with the needed change in teaching practice.
3. In the long-run, all existing teachers retire and even better trained replacements will be required.

III. INSTITUTION BUILDING

A. It is recommended that an Act of Congress be passed with funding legislation to provide for the establishment and support of a new educational form, a regional consortium of institutions whose mission would be educational research, development and organization of an extension service support system that will inter-relate with all levels of education.

GUIDELINES FOR ACTION ON THIS RECOMMENDATION

1. The exact organizational structure of the system will vary according to structure in the region and the type of region involved--urban area, state system, or other regional unit. In any event will have the organization and resources to perform and coordinate the following tasks:

   (1) Provide in-service training, updating, and programs for continuing professional development of teachers.

   (2) Provide for continuous feedback (multi-lateral) from participant schools, teachers and children to curriculum designers.

   (3) Design, adapt, and implement curriculum revisions and development at all levels.

   (4) Basic research in educational science:

      a. Learning theory

      b. Teaching theory

      c. Multidisciplinary analysis

   (5) Provide for R & D application and adaptation of contemporary educational technology.

   (6) Provide for international educational information exchange on both professional and lay levels.

2. Such a consortium system would be patterned after the eminently successful USDA Extension education system. It would require continuing central support on a regular basis from both federal and state funds. Additional support funds for special projects would also be obtained from other sources.

3. A state supported unit could logically be attached to a Land Grant University, as the current USDA Extension Service. It could exist as an organization separate from a university. Each unit would focus on selected aspects of education appropriate to their regional needs, e.g., science education, social studies education, and/or language arts education. Such a unit could focus on basic research and curriculum development on state and regional levels and through extension support, dissemination of information and applied classroom research at local school levels. A state unit should have adequate financial support and linkage with the education system to support workshops and conferences needed to accomplish its mission. The role of the educational extension service would be that of dissemination of information and providing consultant assistance to the local teacher and school. It would not be intended for the consortium to be under direct control of a state department of education or a local school system.

4. Personnel with the necessary knowledge, skills and abilities would be recruited for such centers in order to fulfill its mission. Included would be personnel from colleges and/or universities, state departments of education, local school districts, and industrial firms. Personnel in the extension program would be employed separately as appropriate to that service. The role of an education extension agent patterned after the county agricultural agent, would be to provide a new and needed linkage for the local educational community. These persons would provide leadership for both local schools and other agencies and institutions.

5. The consortium and its extension system would provide personnel and mechanisms for solving many of our current educational problems. Dissemination of information, and interpretation or analysis of information provided by ERIC, could be distributed effectively with supporting consultation through this extension system. The development of educational models and materials could be effectively coordinated and evaluated in a variety of community and neighborhood situations. A network or consortium of this nature would be an effective means for bringing together wide resources including the state departments of education, regional laboratories, research and development centers, colleges and universities, local schools, and industrial firms. The consortial pattern of organization would provide an administrative structure for more effective horizontal and vertical communication and articulation of education practices, methods, and policies and personnel at all levels. This consortium would provide a response and evaluation system for curriculum analysis and improvement which is currently needed.

6. Specific criteria for this successful consortium:

   (1) Cooperative attitudes between member institutions

   (2) A stable and continuing financial basis in budgets of each associated element

   (3) A central physical location

   (4) A capability and a receptivity for change and exploration of innovations

   (5) A capability for continuing program development

   (6) A national system of communication with the educational community

   (7) Operationally stimulates and supports change within and outside its structure

7. Two analogies for the structural organization of the consortium can be found in the university agricultural cooperative extension program and more specifically in the small scale Cooperative College-School Science Program of NSF.

B. It is recommended that within each elementary school building that:

   (a) a room or rooms be designated to function as a mathematics and science learning activities center (laboratory-library, etc.) for the purpose of providing intimate pupil contact with the ideas and processes of these subject areas through use of the available hardware and software that can assist pupils in learning experiences.

   (b) one or more peer teacher(s) who are interested in, and who have above average skills in, the instruction of science and/or mathematics be designated as "the laboratory teacher" and that this person or persons be provided administrative support, release time, and paraprofessional assistance in order to assist the home teachers to provide regularly scheduled pupil-oriented (laboratory) learning activities in mathematics and science.

C. It is recommended that there be established a network of school learning centers as a change agent and an additional means by which voluntary teacher and/or staff initiated innovations could be carried and where a productive exchange of ideas could take place.

RATIONALE

1. No opportunity exists now for teachers to "try out" innovating ideas or to engage in professional and academic discussions with peers about such ideas.

2. All existing support centers for teachers, such as instructional resource centers, film centers and central administrative offices, have an administrative function and are open only from the top administrative level down.

3. The best source of ideas is through commitment and convictions of the classroom teacher.

4. The only effective way of initiating innovative ideas is through commitment and convictions of the classroom teacher.

D. It is recommended that extensive studies and investigation be initiated into the role and the effect of marketing, costs and pricing, public domain, royalties and industrial commitment to the production, dissemination and implementation of educational materials and programs.

RATIONALE

1. We need a full and careful study of policies and financial arrangements involving commercial distribution of materials produced by NSF supported programs.

2. Should "royalty" payments conceivably go in the other direction? The "first man in" among distributors faces heavy extra costs in creating a new market, creating new expectations, solving new publishing and distribution problems, etc. The second company to produce similar materials inherits all of the advantages of this effort, with none of the dollar costs. There are many other considerations: we want distributors to handle innovative materials - there is less dollar return on this than on "ordinary" materials. We want a higher standard of quality or integrity or professionalism - with less merchandising "commercialism" in production and distribution of educational materials. We want few compromises made for commercial reasons. The shared funding pattern of the consortium offers solutions.

3. It is paradoxical that we ask distributors to give more and to earn less. We ask "authorized" distributors to pay money to the government for this privilege.

E. It is recommended that schools explore the vehicle of cross-age classroom teaching teams (teacher-older children and youth-undergraduates, etc.) to serve as new combinations and models of earlier and longer pre-service and in-service education in content, experiences and attitudes reflecting modern curricula changes.

RATIONALE

1. One must learn quickly and effectively to teach successfully.
2. There exists a shortage of elementary school personnel prepared for math-science teaching with a background equivalent to high school level.

F. We recommend that a central (national) project be sponsored to stimulate action consonant with the resolutions of this conference. The project to take the form of a contract between an educational institution (or institutions) and a federal agency to implement some of the recommendations of this Conference.

RATIONALE

1. There is a need to maintain the momentum generated by the Conference.
2. Many people involved with elementary science and mathematics education are not aware of the wide range of available program material in this field.
3. Classroom teachers, as well as educational personnel at other levels, need the support and experience which result from association with successful educational programs.
4. Opportunities should be made available for new and continued experimentation development in math-science education. The educational needs of the country are expanding and changing rapidly. Creative response is a matter of national interest.
5. Program funds may be more readily available for support of grassroots experiments if local personnel have clear information about the relationship of their ideas to developing national programs. Duplication and redundancy are to be avoided through improved communication.

GUIDELINES FOR ACTION ON THIS RECOMMENDATION

THE PURPOSE WOULD BE:

1. To maintain active, up-to-date files and indices of elementary mathematics-science educational information which is available from existing agencies and let it be known that these indices are on hand. They will be used by informed knowledgeable persons to formulate responses to questions asked of the office by educational personnel.

2. To serve a liaison function between science and mathematics spe specialists and the wide range of other people with whom they should be involved. Where necessary, steps will be taken to contact groups that might otherwise be missed; community reorganization councils, teachers' unions, associations of school boards, industries, and professional associations outside of education, etc.

3. To stimulate the existing bureaucracy to action, e.g., state departments of education, - if only by asking how well their constituencies are progressing toward the goals endorsed in the Belmont Conference resolutions.

4. To encourage diversity of participants in all projects by including a reminder to this effect with replies to requests for information. If a school administrator asks for sources from which he may learn about curriculum materials, remind him that proper evaluation of these materials should involve children, teachers, parents, school dropouts, prospective teachers, businessmen, industrial workers, ..., some of whom have not customarily been consulted.

5. To encourage diversity of participation by announcing that the central office will help locate influential informed persons or consultants who can assist in expediting program planning and generation of support.

6. To provide in-service teacher training for implementing new programs in the classroom.

   (a) School Administrators - should again concern themselves with the values inherent in the inquiry approach to learning. Support must be provided for teachers who are attempting to adapt their curriculum to the changing culture. Through math-science, the technology of our culture has come to depend on the fact that flux and change are characteristic of natural events. Natural processes and concern for change are central to the inquiry approach of contemporary math-science curricula.

To update their knowledge of current curriculum trends, principals should accompany teachers to workshops and institutes offered by current curriculum development groups. Administrators must encourage teachers to experiment with new curricula. They must seek and provide the increased administrative and intellectual support necessary for success in such experimentation. Administrators are responsible for the "climate of opinion" in the school. They must interpret the broad goals of the school program for the faculty and the community. They must develop a "climate" in which appropriate productive debate and interplay result in a curriculum that is in phase with the contemporary issues which concern our culure.

(b) Classroom Teachers - should experiment with the new curriculum projects which are designed to provide learners with open-ended experiences more intimately involved in activities which focus on process and change in nature. Students increase their understanding and make valuable contributions to such efforts if encouraged to critique the teaching approaches being used. Students often suggest better ways of communicating ideas if they are given opportunity to cooperate in teaching one another. "Each one teach one" is a way of learning. Regular conferences of "lead teachers" from neighboring schools are an effective force for exchange of ideas and improving the level of instruction being offered. They too gain from the "Each one teach one" mode.

(c) Supervisors - must provide leadership for experimentation within organizational formats that can most effectively bring new programs to classroom teachers. Selection of a special curriculum in each elementary school (AAAS, SCIS, etc.) may result in greater success as the teacher is enabled to concentrate and plan a program that is not made too diffuse by simultaneous influence of several curricular models. Supervisors must provide a two-way communications link between teachers and administrators throughout the school system.

(d) College and University Personnel - can provide special assistance to supervisors and teachers. Courses in Methodology should use the real classroom as a laboratory wherein students are exposed to the realities of classroom living. University instructors should participate in "lead teacher" groups to enable them to provide feedback of experience and information for their students in pre-service teacher training.

IV. COMMUNICATIONS

A. It is recommended that the National Council of Teachers of Mathematics and the National Science Teachers Association form a joint (ad hoc) group to jointly sponsor meetings for (a) elementary administrators and (b) elementary teachers and (c) supervisors. These meetings would be devoted to analysis and discussion of the changing world view reflected in the modern approaches of science and mathematics and its central role in the elementary curriculum.

GUIDELINES FOR ACTION ON THESE RECOMMENDATIONS

1. Workshop meetings for administrators would focus on the characteristics and goals of the various programs and incorporate observations of classroom activities from these programs through demonstration and/or video tapes. The purpose of these meetings would be to assure that elementary school administrators possess understanding and direct acquaintance with the existing programs.

2. Meetings for teachers and supervisors would require more time to enable presentation of an overview of the various programs, and to directly involve each participant in representative classroom activities. Each teacher would have an opportunity to experience and more thoroughly understand the nature of the several available programs.

3. It is proposed that these associations develop and prepare "package" programs which would be available to directors of similar conferences to be held across the nation. The package could include a suggested agenda, factual information, suggested mode of operation, film clips, and sample materials for participant activities.

4. There could be many variations of these regional conferences. They could involve several states or only one school district. The program could be specific and discrete or it could be incorporated as a part of a larger comprehensive program.

B. To assure the effective dissemination of the outcomes of the Belmont Conference, we recommend that a brief (one page) summary of the purpose and resolutions of the Conference should be prepared and published in such journals as: The Arithmetic Teacher, The Instructor, ASCD Journal, NSTA(The Science Teacher), and the New York Times.

Notations should be included which would inform the interested reader as to the availability of the full report.

APPENDIX C

Participants and Observers at Belmont Conference

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